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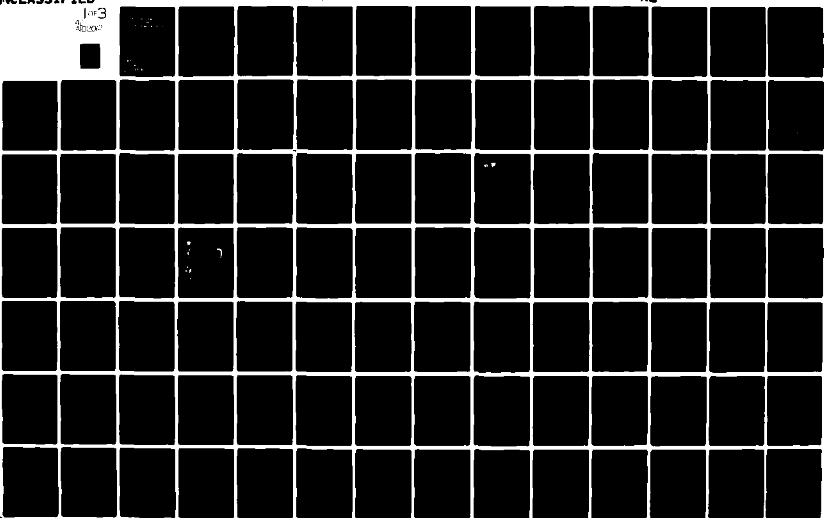

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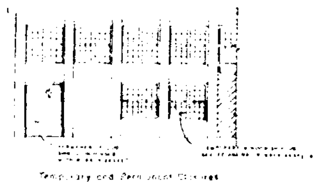

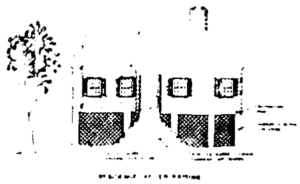

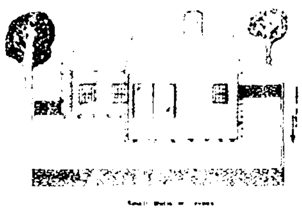

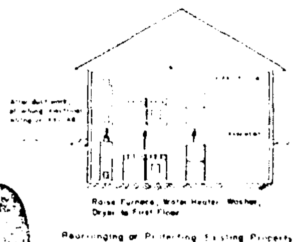

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this study is to examine the phyical and economic feasibility of a number of nonstructural flood control measures and develop criteria for their use. Eleven such measures are selected; this report evaluates their overall physical and economic feasiblity. The measures studied are: temporary and permanent closures for openings in existing structures; raising existing structures; construction of new structures on fill or columns; small walls or levees (CONTINUED)

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around structures; relocating or protecting damageable property; relocating existing structures and/or contents out of a flood hazard area; flood forecast, warning and evacuation; use of water resistant materials in construction; regulation of development of flood plain land through zoning ordinances, subdivision, regulations and building codes; public acquisition of title or easement to flood plain land; and flood insurance. Cost estimates, advantages, disadvantages and references are provided for each measure. A senisitivity analysis of flood damage in relation to various hydrologic, hydaulic, and economic parameters was conducted. These parameters include elevation-frequency relationship, frequency 'skew', depth-damage relationship, value of structure contents as a percentage of the value of a structure, type of structure, and location in the floodplain. The effectiveness of selected nonstrucutral measures was then evaluated by computing the damage reduced for several levels of protection. It was found that nonstructural measures have an important role alongside structural measures in reducing flood losses. Every measure investigated was found to be physically and economically feasible in some flood hazard situation, and particular applications and limitations were identified.

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PHYSICAL AND ECONOMIC FEASIBILITY OF NONSTRUCTURAL FLOOD PLAIN MANAGEMENT MEASURES

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PHYSICAL AND ECONOMIC FEASIBILITY OF NONSTRUCTURAL FLOOD PLAIN MANAGEMENT MEASURES

CONTENTS

APPENDICES

PREFACE

This report presents the findings of an investigation into the physical and economic feasibility of eleven nonstructural flood plain management measures. These measures were selected from a larger number of possibilities principally because they appeared to be the ones being used most frequently and limited time and budget necessitated a reduced number. As a result of a detailed examination of each measure, some general conclusions and observations regarding nonstructural measures were reached. These are discussed in Chapters 1 and 2 under concept and characteristics and should serve as an introduction to the subject and to some of the related problems and questions. Chapters 3 through 13 examine each nonstructural measure in detail. Each Chapter contains a description and illustration of the measure, a discussion of its physical feasibility, an engineer's cost estimate, an evaluation of its economic feasibility, a summary of advantages and disadvantages, and a list of important references. In some cases it was impractical to estimate cost. In these cases only the cost items were identified. The evaluation of economic feasibility was made by comparing estimated costs with damage reduced. Cost estimates included only essential items in an attempt to estimate a minimum cost. Damage reduced was computed using 1970 Federal Insurance Administration depth-damage and 1974 elevation-frequency data. This gave a maximum damage reduction estimate. Using minimum cost and maximum damage, an "optimistic" estimate of economic feasibility was obtained. Where it was impractical to make a quantitative evaluation of feasibility, some general observations are presented.

Appendix A contains the detailed damage analyses used in establishing economic feasibility. There are numerous variables to consider in estimating expected annual flood damage and Appendix A presents findings on the sensitivity of damage estimates to each of these variables. These data should be useful to any person desiring to understand or estimate the significance of a particular variable on flood damage estimates. It should be pointed out, however, that the computed damage values are based upon generalized elevation — frequency and depth — percent damage data and should not be used in estimating damage where site specific data are available. Appendix B contains a summary of the engineer's cost estimates for selected measures. Appendix C contains information which was developed during the investigation and which it was thought would be useful to anyone investigating forecast, warning, and evacuation as a nonstructural alternative. Appendix D contains similar information on construction materials and methods to reduce damage. A bibliography of papers, reports, texts and other literature collected during the study is cited alphabetically in Appendix E.

ACKNOWLEDGEMENTS

Many people deserve recognition for their role in the preparation of this report. Michael Burnham did both the research and writing on forecast, warning, and evacuation. David Williams did the structural analyses for the temporary and permanent closures, prepared data for the economic analyses, and made many hand computations to check the results. Computation of expected annual flood damage was made using a Hydrologic Engineering Center computer program written by Harold Kubik. Harold was instrumental in making changes to the program to facilitate the large number of computations required for the investigation. Jeanne Tew had the awesome task of typing the final manuscript and Roger Nutter the difficult and lengthy job of drafting the over sixty drawings. Darryl Davis, Chief, Planning Analysis Branch, provided much needed discussion and insight on many theoretical and policy questions and Bill Eichert, Director of the Center, offered his encouragement and support throughout.

In addition to the HEC staff, the author had the privilege of receiving review comments from several persons with considerable experience in flood plain management. James Goddard, John Sheaffer and D. Earl Jones, Jr., offered numerous important comments and suggestions on an earlier draft and these led to an extensive revision and the addition of much new material. James Owen reviewed a draft of the material on forecast, warning, and evacuation and offered many valuable suggestions. David Justice prepared engineer's cost estimates for many of the measures and provided helpful insight into the factors which influence cost at the local level.

Funding for the investigation was provided by the Institute for Water Resources, together with considerable patience from its Director, A. J. Fredrich, who kept thinking the final report was coming soon — when it was really later.

SUMMARY AND CONCLUSIONS

What are the salient findings of this study? They are that,

- Nonstructural measures have an important role alongside structural measures to reduce our nation's flood losses.
- They are physically and economically feasible to many flood hazard situations and are being implemented in numerous communities around the country.
- They have particular applications and limitations which have been identified and which can be used to evaluate their feasibility in specific flood situations.
- Estimates of flood damage and damage reduced are sensitive to a number of variables and the importance of the variables has been identified and the magnitude of this sensitivity has been quantified.
- Knowledge of physical feasibility and economic feasibility can be coupled with presently available analytic and data management technology to efficiently, effectively, and economically formulate and evaluate nonstructural plans.

To state that nonstructural measures have an important role alongside structural measures is nothing new. This has been stated repeatedly by numerous individuals, task committees, and agencies over the past 30 years. Most recently, recognition of this fact is emphasized and made mandatory in enactment of the National Flood Insurance Program, Section 73 of the 1974 Water Resources Development Act, and publication of the Water Resources Council's "A *Unified* National Program for Flood Plain Management." The findings of this investigation also reaffirm this concept.

Every measure investigated was found to be physically and economically feasible in some flood hazard situation. More importantly, applications of every measure were found in flood plains around the country. The literature — published papers, reports, etc. — have been an exceedingly poor indicator of the application of these measures. Individuals and communities simply act to reduce flood losses and these actions rarely result in a written document. The resourcefulness and creativity of these actions is often amazing. Nonstructural measures are feasible because analyses show this to be true and because they are actually being implemented by individuals and communities.

The foregoing general conclusion regarding feasibility should not be misunderstood. Nonstructural measures, like structural measures, have their particular applications and limitations. Because a reservoir is feasible on a main stem river does not mean it is feasible on a local tributary. Because flood plain zoning is effective for future development does not mean it is for existing. This study attempts to define explicitly the physical and economic applications and limitations of each measure. To do this, both the measure and the flood hazard situation has to be made explicit. Does nonstructural measure mean raising a structure in-place or relocating it off the flood plain; temporary closures or land acquisition; a small wall or levee or flood insurance? Whether a particular measure is feasible, physically or economically, can only be determined by answering these and other specific questions. The findings of this study are not being put forth as the end, but only as a beginning or perhaps more accurately as a contribution to this end.

Expected annual flood damage and damage reduced were computed and the data plotted for a wide range of hydrologic, hydraulic, and economic conditions. Costs were compared with damage reduced for a number of measures. These analyses show the economic feasibility of these measures and the sensitivity of the damage estimates to important variables. This quantification of expected annual damage makes explicit the methodology involved and should prove useful to persons unfamiliar with it. The sensitivity findings show some variables more important than others and by how much. They also provide an estimate of adjustments which should be made for atypical situations. These findings have led to a much better understanding of flood damage estimation than was available before.

Lastly, the study has shown the way for developing an analytic and data management technology for nonstructural formulation and evaluation. Findings concerning physical and economic feasibility have identified important parameters and variables which are needed to properly formulate and evaluate nonstructural measures. For a particular flood plain, data would be collected for each parameter and variable. Currently available analytic capability for damage computations and data management technology would be used to process these data and make analyses. Various spatial display devices are also available to facilitate presentation of the results. This coupling of a deeper understanding of what is important to explicitly evaluate each measure, with the technology to make this evaluation and process the data, should prove to be a significant step toward more effective consideration of nonstructural measures in planning.

The measures were investigated and disscussed as individual flood plain management actions. In application, however, it is likely that they will be used in a variety of combinations. Some will be used for existing development, others for future; some for residential structures, others for commercial/industrial; some at locations of frequent flooding, others where it is less frequent. For each structure or parcel of land the most appropriate action should be selected and the management plan should be the sum of the individual parts.

Damage data for different hydrologic conditions and types of structures are tabulated and plotted in Appendix A. These data were used in this investigation and may be useful to others in estimating expected annual damage. The user should be cautioned however. First, the damage values were computed using generalized frequency and depth-damage data. These values should not be used in analyses where more detailed site specific data are required. Second, the data presented are estimates of damage and damage reduced which may not be the same as a benefit. An examination of the other savings which might be included as a benefit was beyond the scope of this study.

TERMINOLOGY AND SYMBOLS

FIA - Federal Insurance Administration, U.S. Department of Housing and Urban Development.

1970 FIA Data - Elevation versus frequency and depth versus damage data presented in "Flood Hazard Factors, Depth-Damage Curves, Elevation-Frequency Curves, Standard Rate Tables", Federal Insurance Administration, September 1970.

1974 FIA Data - Depth versus frequency and depth versus damage data presented in Sections 7.1 and 7.2 of an unpublished report entitled "Flood Insurance Rate Calculation Computer Program" prepared by D. J. MacFadyen for the Federal Insurance Administration, 3 April 1974. The depth-frequency data are shown in Figure A-1, Appendix A, and were used in all analyses in this study.

Huntington District Data - Depth versus damage data presented in an unpublished report by the Huntington District, Corps of Engineers entitled "Technical Report on Representative Flood Damage to Residential Properties", 1977.

1970 FIA Data Modified - Depth versus damage data identical to 1970 FIA Data above 0.1 feet, modified slightly below 0.1 feet to approximate Huntington District Data. These modified data are tabulated in Table A-1, Appendix A, and were used in most analyses in this study.

1SNB - One story, no basement structure. The depth-damage relationship for this structure is tabluated in Table A-1, Appendix A.

2SNB - Two or more stories, no basement structure. See Table A-1, Appendix A for the depth-damage relationship.

1SWB - One story, with basement structure. See Table A-1, Appendix A for the depth-damage relationship.

2SWB - Two or more stories, with basement structure. The depth-damage relationship for this structure can be found in Table A-1, Appendix A.

VC/VS - Ratio of value of contents (VC) to value of structure (VS). For most analyses in this study a ratio of 0.35 was used.

FHF - Flood hazard factor. The distance in feet between the elevation of the 100 year event and the 10 year event. Each frequency relationship is identified by a flood hazard factor ranging from 1.0 to 20.0 feet. See Figure A-1, Appendix A. A low FHF is characteristic of a wide, flat flood plain; a high FHF is characteristic of a narrow, steep flood plain.

Skew M - The depth-frequency curves presented in the 1974 FIA Data and shown in Figure A-1, Appendix A. These curves approximate the median curves presented in the 1970 FIA Data, hence the use of the letter M in this study.

Exceedance Interval - The average time interval, in years, in which a flood of a given size is exceeded as an annual maximum. For example, 10 years, 20 years, etc.

Frequency - The exceedance frequency. The probability that a flood event will exceed a specified magnitude in a given time period; usually one year, expressed as a percentage. For example, 100 percent for the annual event, 50 percent for the 2 year event, 1 percent for the 100 year event.

CHAPTER 1

THE CONCEPT OF NONSTRUCTURAL MEASURES

Historical Development

The word "nonstructural" has been used for many years as an antonym to the word "structural" to describe alternatives to dams, levees, diversions and channel modifications as means to reduce our nation's flood losses. Over the years the concept of nonstructural measures has been expressed by many people in many different ways. In 1945, Gilbert White called for a "geographical approach" to flood control planning and described a variety of adjustments which could be made (1). Some ten years later Hoyt and Langbein articulated the same need and suggested a "unified flood-management" approach be adopted as national policy (2). The concept became national policy in 1966 with the publication of House Document No. 465 and Executive Order 11296 which call for dissemination of information on "alternate methods" and a "broad and unified effort" to lessen the risk of flood losses(3). "Nonstructural" began to be used as the descriptor for these measures in House Document 465 and in an earlier paper by James(4). The concept being expressed by these and other efforts was that there are a variety of ways which can be, and in fact have been, used to reduce flood losses to existing and future development. Traditional "structural" means, which are designed to control flood waters, are one way, however there are a variety of other means and these should be used also. It is not either/or, rather both.

Identification of Nonstructural Measures

Measures which have been termed nonstructural include,

- Installation of temporary or permanent closures for openings in structures.
- Raising existing structures in-place.
- Constructing new structures on fill or columns.
- Constructing small walls or levees around structures.
- Relocating or protecting damageable property within an existing structure.
- Relocating existing structures and/or contents out of a flood hazard area.
- Use of water resistant materials in new or existing structures.
- Regulation of development of flood plain land by zoning ordinances, subdivision regulations and building codes.
- Acquisition of title or easement to flood plain land.
- Flood insurance.
- Installation of flood forecast and warning systems with an appropriate evacuation plan.
- Adoption of tax incentives to encourage wise use of flood plain land.
- Placement of warning signs in the flood plain to discourage development.
- Adoption of development policies for facilities in or near flood plain land.

While this list may not include all nonstructural measures it includes most of them. All except the last three — tax incentives, warning signs and development policies — are discussed in this

report. The three were omitted because they seem to be used less frequently, although they are not less important, and because limited time and funds necessitated a lesser number.

Recent Legislation

House Document No. 465 and Executive Order 11296 provided needed policy guidance for formulating nonstructural plans. Prairie du Chien (1970) and Charles River (1972) were two of the earliest Corps studies to emphasize nonstructural solutions based upon this guidance. Formal legislation in the form of the 1973 Flood Disaster Protection Act and the Water Resources Development Act of 1974 extended and expanded the emphasis on nonstructural. The 1973 Act took a significant step toward implementing the nonstructural approach by encouraging and requiring the purchase of flood insurance as a means of reducing financial loss to a property owner. In addition, the 1973 Act encouraged and required adoption of land use regulation and raising or flood proofing of new structures to or above the 100 year flood elevation as a part of the insurance program. The insurance premium gave the property owner an explicit statement of the cost of flooding to him and gave him incentive to seek alternative means of occupancy to reduce this cost. In addition, this Act and the associated FIA regulations influenced the formulation and evaluation of other nonstructural measures which are considered for implementation in project planning.

Section 73 of the 1974 Act called for explicit consideration of nonstructural measures in Federal planning and provides for cost sharing of such measures. Section 73(a) of this Act requires that,

> "*In the survey, planning, or design by any Federal agency of any project* involving flood protection, consideration shall be given to nonstructural alternatives to prevent or reduce flood damages including, but not limited to, floodproofing of structures; flood plain regulation; acquisition of flood plain lands for recreational, fish and wildlife, and other public purposes; and relocation with a view toward formulating the most economically, socially, and environmentally acceptable means of reducing or preventing flood damages".

The cost sharing provision of Section 73(b) spelled out for the first time the extent to which non-Federal interests would be required to share in the cost of nonstructural projects. It called for non-Federal participation to be comparable to the value of the lands, easements, and rights-of-way required for structural protection, but not to exceed 20 percent of the project costs. This provision addressed an issue which had been unresolved in previous policy statements and legislation, and attempted to place nonstructural measures on a comparable basis with structural measures.

Recent Research

While nonstructural measures have been identified conceptually for sometime, until recently there has been little work undertaken to provide specific information on what actions are necessary for implementation; costs of implementation; effectiveness in reducing flood losses; social, environmental, and economic impacts of implementation; and identification of conditions which are most favorable for the application of each measure. One of the first efforts of this type was by Sheaffer in 1960 when he examined ways to flood proof structures (5). In 1965 House Document No. 465 called for "programs to collect, prepare, and disseminate

information . . . on alternate methods of reducing flood losses . . ." Two years later Sheaffer prepared an introductory manual on flood proofing and in 1972 the Corps of Engineers published specific information on building requirements for structures in flood hazard areas (6,7). In the last few years the Department of Housing and Urban Development (principally the Federal Insurance Administration), the Water Resources Council, and several States have taken the leadership in sponsoring and publishing research on this subject (8,9,10,11). Still the number of contributions with detailed technical information is very small. With passage of the 1974 Water Resources Development Act the need for technical information became more urgent. Corps offices began conducting special studies in-house within the context of project studies, or sometimes awarded small contracts for studies on the feasibility of specific nonstructural measures. In most cases this work was not published or distributed Corps-wide but simply served the needs of a particular study. It was against this background that the objective of this study was formulated.

Study Objective

The objective developed for this research was to examine the physical and economic feasibility of a number of nonstructural measures and to develop, where possible, specific criteria for their use. It was desired to understand the conditions when each measure was appropriate and when inappropriate. What are the characteristics of each measure which leads it to be adopted in one instance, but not in another? In essence the objective was to learn more about these actions called nonstructural flood plain management measures.

The study approach was to select eleven nonstructural measures for detailed investigation. Each measure was identified as to its purpose and the actions required to achieve this purpose. This information is reported in a brief description of each measure with accompanying drawings. Physical feasibility was established by examining the physical characteristics of each measure, by reviewing examples of implementation, and in some cases by making structural analyses. Physical feasibility had to be limited to what is feasible within the normal limits of costs and damage reduced. Some measures may be feasible in that the technology exists, but the cost may be out of the question for the damage reduced. Costs and damage reduced were likewise examined in the context of what is practical. Costs are often site specific and highly variable. An effort was made to identify specific cost items for each measure. Some items are base costs and are required, regardless of how the measure is implemented; other costs are optional and apply in some circumstances but not in others. An engineer's estimate of minimum cost was made for most measures for the purpose of comparing it with damage reduced. A detailed sensitivity analysis was performed using various generalized hydrologic, hydraulic and economic data. A brief summary of damage reduced as a part of this analysis is reported in each Chapter. The details of the analysis are presented in Appendix A.

Following the detailed examination of each measure some general characteristics of nonstructural measures as a technology were identified. These are discussed in the next Chapter. It was hoped that a better understanding of nonstructural measures overall, would lead to more appropriate specific application.

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CHAPTER 2

CHARACTERISTICS OF NONSTRUCTURAL MEASURES

This Chapter discusses some of the characteristics which distinguish nonstructural measures from structural. It may seem trite to say that there are differences, but this fact is often forgotten and misunderstandings develop as to the role nonstructural measures play in flood plain management. Each type measure — whether structural or nonstructural — has its appropriate place in the present and future management of our nation's flood plains. When a measure is evaluated for a situation for which it is not suited, it is unfair to generalize and say the measure is ineffective or too costly in all situations. A reservoir may be appropriate to protect several communities on a main stem river, but inappropriate to protect a subdivision on a tributary. Similarly, providing temporary or permanent closures for doorways may be appropriate where shallow flooding occurs, but inappropriate where the velocity and depth are high. A levee protects existing development, and zoning seeks to protect future development. One measure may be desired by the community or individual homeowner, another measure may not be desired. Each measure has its appropriate place and the principal task is to find the most appropriate measure for each specific flood hazard and community situation.

Local/Individual Nature

Most nonstructural measures are actions taken to individual structures or to land in or around a community. Structures are protected by keeping water out, elevating in-place, constructing a small wall or levee, relocating contents, moving the structure and/or contents, building a structure higher, or using water resistant materials. Specific areas of land are regulated or acquired in fee or easement. Even evacuation, which may be part of a regional forecast/warning system, requires individual action to save life and property. Flood insurance also requires individual, as well as local community action. In each of these cases action is taken on individual structures or to specific plots of land and because of this it is necessary to know the specific characteristics. This should include location, type, condition, use, and depth and frequency of flooding. By way of contrast, reservoirs, levees, diversion works, and channel modifications protect property without modifying individual structures, and until recently did not attempt to regulate land use. Frequently structural measures are not even visible to the individuals being protected — they are over there, or upstream. They deal with the flood, rather than with the *structures being protected. Protection is provided not by modifying the structure, but by* storing, diverting, or channeling flood waters.

One of the fundamental questions raised by this local/individual characteristic is that of federal interest. Should the Federal Government be investigating ways to alter individual structures? This question is addressed here because the answer determines our willingness to investigate the feasibility of nonstructural measures. There are two answers to the question — both positive. Since the law requires that Federal flood control planning consider nonstructural alternatives and since nonstructural alternatives means investigating ways to protect individual structures there is no choice but to get down to the level of individual or small groups of structures. Whether or not the Federal Government implements any conclusions or recommendations regarding nonstructural measures is another question. The law states they should be considered. The information can be passed on to the local government or individual

property owner as technical information for their implementation, or if supported by the local community, the Congress, and the President, it may lead to Federal implementation. A second justification for Federal consideration of nonstructural measures is that, if the Federal Government uses public funds to investigate means to solve public problems, it should investigate all means provided they are within the general study authority set forth by Congress.

Existing/Future Development

Measures which are designed to control flood waters — reservoirs, levees, channel modifications, diversions — protect both existing and future flood plain development. For nonstructural measures, however, some measures are designed principally for existing structures, some only for future, and some for both. Relocating a structure off the flood plain, for example, is intended for existing structures; flood plain regulation, on the other hand, is principally for future development. Keeping water out of a basement which is already built is quite a different problem from designing and constructing a new structure to do the same thing. Existing structures pose special problems because they are already built and use patterns have been established. Also, there is often uncertainty regarding the nature of the materials and workmanship used to construct the structure and of its present condition. This is an important question if it is desired to keep water out and subject it to hydrostatic loads. When this uncertainty exists either the measure is not used or it is used conservatively. Also, there is usually less flexibility in applying nonstructural measures to existing as opposed to new structures. Aesthetics, lot lines, elevations, and zoning, are all established and must be modified and the desirability to do so may be a significant factor in implementing the measure.

Traditionally, flood control planning has focused on protecting existing structures because authorizations were made in response to floods which had recently caused damage to existing structures. The need to protect these structures will continue, but, in addition, there is a need to give equal attention to future development. While future land enhancement was sometimes a part of a protection plan it was usually secondary and limited. Much of our flood plain land is undeveloped and federal policy mandates that we encourage wise use of this land. Nonstructural measures are particularly suited for this task. Thus, in planning with these measures the distinction between existing and future development should be recognized and the appropriate measure or measures investigated for each.

Costs

Since nonstructural measures can be used for individual and small numbers of structures or for small acreage of land their investment cost can be quite low. Most structural measures on the other hand are normally large scale and have a large investment cost. This is not to say that for a given level of protection the **cost per structure** is any greater or less with one type measure or the other, this would have to be evaluated on a project by project basis. Rather it says that because nonstructural measures can be used on a very small scale the first costs can also be small making it especially attractive in situations where investment capital is limited. Measures which allow a wide range of first costs may have a better opportunity for implementation than those which have a comparatively high first cost. Being able to invest at several levels also encourages a variety of investors. The Federal Government may be willing to relocate several hundred structures at a cost of several million dollars; a community using grant money may opt for relocating ten or twenty structures for several hundred thousand; or a homeowner may choose to raise his structure for several thousand. Nonstructural formulation allows this flexibility.

The other side of this cost/number of structures coin is economy of scale. Structural measures often take this factor into account in sizing. Nonstructural measures offer a similar opportunity for economic savings, however, there is little contractor's bid data in a form by which this savings can be measured. Fabricating two hundred flood shields is surely less costly per unit than one; raising fifty homes would undoubtably cost less per unit than one; and hopefully regulating 100 acres would not be ten times the cost to regulate 10 acres. In addition, to take advantage of this savings it is necessary that individuals agree to simultaneous implementation which may require a coordinated effort.

Damage Reduced

Damage reduction has traditionally been computed by estimating the difference in expected annual damage with and without a particular measure. The expected value is computed by weighting damage caused by different levels of flooding by the probability of each level occurring. By reducing either the frequency of flooding, or the amount of damageable property susceptible to flooding, damage is reduced. This method can be used for individual structures or groups of structures and for nonstructural, as well as structural measures.

Another method which has been used, and considered for use as a surrogate for estimating damage reduced, is flood insurance premiums. Theoretically, the actuarial rate is computed as the expected annual damage plus an administrative or load charge. In order for the premium to be a valid surrogate for expected annual damage it must be based upon the actuarial rate and be "closely linked to expected value of damages to the flood plain occupant" (1). At the present time this may or may not be the case since several insurance rates are available and the actuarial rate is computed using generalized depth-damage and elevation-frequency data developed nation-wide. Both the subsidized rate and zone rate are established to encourage purchase of flood insurance so they do not necessarily reflect actual expected damage. The elevation rate is intended to represent the actuarial rate, however, it is based upon generalized data. In any particular community the actual expected annual damage may be considerably different. Premium savings computed using these rates may be much higher (or lower) than damage reduced by a particular action. One example is discussed in Reference 2. In addition, it should be recognized that use of insurance premiums does not include "noninsurable" damages to yards, outside improvements, etc.

Since the idea of premium savings is analogous to damage reduction it should be computed as the difference in premium with and without some particular action. Existing structures which are in communities under the Flood Insurance Program are eligible for coverage at subsidized rates, thus if a structure were modified in some way the savings would be the difference between the subsidized and some lower actuarial rate, and in general would be small. Existing structures not in the Program would not realize a premium savings although damage could be reduced. New structures locating in the flood plain under the Program (after a Flood Insurance Rate Map has been established) must be protected to the 100 year flood level, thus any premium savings would be the difference in premium at the 100 year level and some higher level to which the structure would be built, or between the 100 year level and some alternative site off the flood plain where the premium would probably be zero.

Insurance premiums are of particular interest when considering nonstructural measures because they provide the individual property owner with a measure of the cost of flooding to

him (although it may be a subsidized cost) and the savings in costs which can be realized if steps are taken to reduce the hazard. This is an incentive for greater implementation of nonstructural measures. This savings may be small because of the regulatory practice of offering subsidized rates to existing structures and requiring new structures to build at or above the 100 year level and because premiums do not reflect "noninsurable" damage. Also, a savings is not available for all adjustments. Raising a new or existing structure to the 100 year level, keeping a structure out of the flood plain, or removing structure and/or contents to a flood-free site all may yield a premium savings. Other adjustments such as closures for openings, rearranging or protecting damageable property within a structure, or building a small wall or levee, do not at the present time, result in a premium savings.

Degree of Protection

Degree of protection has traditionally been used as an indicator of project performance to define the exceedance interval of the flood event at which flood damage begins. It is the **minimum** protection provided by a project and is associated with a particular river location. Structural measures, because they are designed to control flood waters, generally provide the same protection to all structures at that location. For example, a reservoir or levee by controlling a particular flood event controls it for all structures within the flood plain of that event. It is more difficult to provide this type protection with nonstructural measures because most measures are applied to individual structures and each structure varies as to type and location in the flood plain. Also, a nonstructural plan is likely to be a mix of measures and there are limits to the feasibility of each type measure. This is especially the case for existing structures. Uniformity of protection is less difficult for new structures. Flood plain regulation, elevating new structures, and flood plain acquisition all provide the opportunity for uniform protection of future development. In a practical sense when developing a plan using nonstructural measures it is likely that some measures will provide protection to one level and others to another, and it will be difficult to provide the same protection for all structures. It is likely each structure or group of structures will have its own degree of protection. For this reason the indicator, degree of protection, in its traditional sense as one value for all structures, is not as useful in nonstructural formulation.

In addition to the difficulties mentioned above, there is also the fact that different nonstructural measures by their nature provide different degrees of protection. If a structure is raised to the 100 year flood elevation the degree of protection would be 100 years. However, a structure removed from the flood plain or prohibited from locating in the flood plain has very large protection. The term "protection" itself is relative when applied to nonstructural measures. A small wall or levee is designed to keep flood waters from coming into contact with both structure and contents. Temporary or permanent closures, however, while protecting the contents incur residual damage to the structure. Flood insurance has the unique feature that it doesn't protect (reduce damage) in the traditional sense, but indemnifies the policy holder against financial loss.

A major factor when establishing degree of protection is the severity of damage should the protection be exceeded. Selecting the appropriate measure for the hazard situation, together with proper design can minimize this potential damage. For example, closures on doors or windows would not be appropriate if walls and floors could not withstand the hydrostatic forces. A structure raised on columns should be designed with the knowledge that it is likely to

be inundated and surface wave action may occur. A structure located where it is subject to high velocity flow would be more appropriately moved than protected. Properly protected, a structure should not incur excessive damage if that protection level is exceeded.

Some nonstructural measures require warning time to implement: for example, flood shields for doorways and windows, and gates for openings in walls or levees, or evacuation of people and property. The reliability of protection provided by measures which require warning is obviously less than for those which require no warning. In fact, it may mean the difference between protection and no protection. Once again the key to wise use of such measures is to use them where the risk of their not being in-place is minimized. This could be in situations where there is normally ample warning, where the damage incurred is small, or where the measure is the best alternative available.

This discussion on degree of protection suggests that the traditional concept of providing a uniform, minimum protection for all structures is not appropriate with nonstructural measures. Rather, protection performance should consider damage reduced, risk, consequences of the protection being exceeded, cost, and the most likely alternative. Movement away from the traditional concept would seem to enhance the ability to formulate viable, implementable nonstructural plans.

Implementation

In different communities across the country there are examples where each of the nonstructural measures discussed in this report have been implemented. These measures are not new and untried. Most measures in fact have been used for decades; some for centuries. It is not that the measures themselves are new, nor that they haven't been used before, rather it's that, in the past, they have not been considered as a viable planning alternative or recommended for implementation by most planning bodies. Consequently they are "new" to most water resource planners. Also, their individual nature and low capital cost has not attracted the same attention as large scale, high capital cost projects. The amount of research has been small, the number of publications few, and our knowledge weak. However, many communities and individuals, sometimes acting out of wisdom and other times out of necessity, have used these measures to reduce the danger of flooding and the potential flood damage. It was not the purpose of this investigation to identify examples of implementation, however, during the investigation numerous examples were found. Some of these are mentioned below. Where possible a written reference is cited.

Temporary and Permanent Closures for Openings in Existing Structures - Examples in LaGrange, Illinois, and Pittsburgh, Pennsylvania, are cited in Sheaffer's early work (3). Other examples are near Atlanta, Georgia, and in Prairie du Chien, Wisconsin, where an industrial building was flood proofed, although these have not been published.

Raising Existing Structures - A detailed example of one existing structure which was raised along Peach Tree Creek, Georgia, is described in Reference 5. Additional examples can be found in Wayne Township, New Jersey, and New Orleans (Southeast), Louisiana. Descriptions of these raisings have not been published.

Small Walls or Levees Around New or Existing Structures - Examples of the implementation of this measure are described in Reference 4. These examples are in the Peach Tree Creek Basin near Atlanta, Georgia.

Rearranging or Protecting Damageable Property Within an Existing Structure - Based upon interviews conducted as part of studies in Atlanta, Georgia, and Charlotte, North Carolina (4), it is commonplace for homeowners experiencing frequent flooding to relocate damageable property within the structure. Protecting utility wiring, furnaces, appliances, and motorized equipment received top priority.

Removal of Existing Structures and/or Contents from a Flood Hazard Area - Five examples of relocation are: Kingery West, Illinois (near Chicago, about 40 homes); Oakdale, Tennessee (13 families, 1 church); Big Stone Gap and Clinchport, Virginia; Chester, Pennsylvania (commercial structures).

Flood Forecast, Warning and Evacuation - Both Gatlinburg, Tennessee, and Wise County, Virginia, have implemented self-help flood forecasting systems. During an April 1977 flood an early warning allowed the people of Wise County to evacuate, saving lives that may otherwise have been lost.

Elevating New Structures - Examples of elevated new structures in Mississippi, Louisiana, Illinois, Delaware and other states are described in References 3 and 6. The methods used include posts, piles, piers, walls, pedestals and earth fills.

Construction Materials and Practices for New or Existing Structures - Examples of this adjustment were also found during the interviews conducted as part of the study described in Reference 4. Installation of indoor/outdoor carpet and water resistant floor tile were identified as water resistant materials. Other examples can be found in the Golden Triangle area of Pittsburgh, Pennsylvania.

Zoning Ordinances, Subdivision Regulations and Building and Housing Codes - Reference 7 identifies numerous communities from California to Massachusetts which have implemented various types of flood plain regulations and both References 7 and 8 cite draft ordinances being used by many communities.

Public Acquisition of Flood Plain Land - The Forest Preserve District of DuPage County, Illinois acquired 80 to 90 acres of flood plain land along Salt Creek. One parcel included a subdivision — Kingery West — where the owners of approximately 50 homes were relocated and their structures demolished (9).

Flood Insurance - As of March 1977 the Federal Insurance Administration had over 900,000 flood insurance policies in force in over 15,000 communities. The average policy for a residential structure was for $28,900. and the average premium for all type structures was $75. per policy per year.

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CHAPTER 3

TEMPORARY AND PERMANENT CLOSURES FOR OPENINGS IN EXISTING STRUCTURES

Description

Structures whose exterior is generally impermeable to water can be made to keep flood water out by installing watertight closures to openings such as doorways and windows. While some seepage will probably always occur, it can be reduced by applying a sealant to walls and floors and by providing a floor drain where practical. Closures may be temporary or permanent. Temporary closures are installed only during a flood threat and therefore need warning time for installation. Specific measures which may be taken are described below.

Doorway Closures - Exterior doors do not normally seal tight enough to prevent seepage around the door jamb. Installation of a rubber type gasket and the means to press the door against the gasket to create a tight seal would be adequate for low heads (0 — 1 feet). A more certain means is the use of flood shields. Shields are normally of aluminum, steel or wood and made to the height and width desired. In commercial/industrial structures they may be permanently installed at the doorway on hinges or rollers for swinging or sliding into place, or more often, particularly for residential structures, they may be stored nearby for installation on brackets or anchor bolts at the time of a flood. The shield seals against the door jamb with a rubber type gasket. Doorways not used are sometimes closed permanently with concrete blocks, bricks, or other relatively impermeable materials.

Window Closures - Normal window glass will take little hydrostatic pressure and is especially vulnerable to breakage by floating debris. Flood shields are commonly used to protect windows and prevent water from entering. As with doorway shields they may be permanently installed on hinges or rollers at the opening or stored elsewhere and installed temporarily during floods. Another alternative is to install heavy duty plexiglass or glass block (for basement windows) which can normally withstand hydrostatic pressures of several feet. Large display windows in commercial structures are sometimes protected by installing weep holes at the base of the window. This allows water on the inside to equalize the hydrostatic pressure on the window, but it is prevented from entering the remainder of the structure by parapet walls. Windows not needed can be permanently closed with blocks, brick or other impermeable material.

Seals - Waterproofing sealants are sometimes applied to generally impermeable walls and floors to further reduce seepage. Sealants are particularly effective on brick veneer, cement block, reinforced concrete and similar masonry type surfaces. Cracks in the masonry can be filled by caulking.

Sewer Lines - Sanitary sewer backflow can be prevented by installation of a gate valve and by installing valves in floor drains.

Sump Pump - Some seepage is likely to enter a structure even though it is termed "watertight". It is desirable, therefore, to have a sump pump available to remove seepage. The pump discharge should be located above the design flood elevation.

The above measures are those generally used to keep water out of a structure. They can be used in any combination depending upon specific site conditons. Figure 3-1 illustrates the use of these measures.

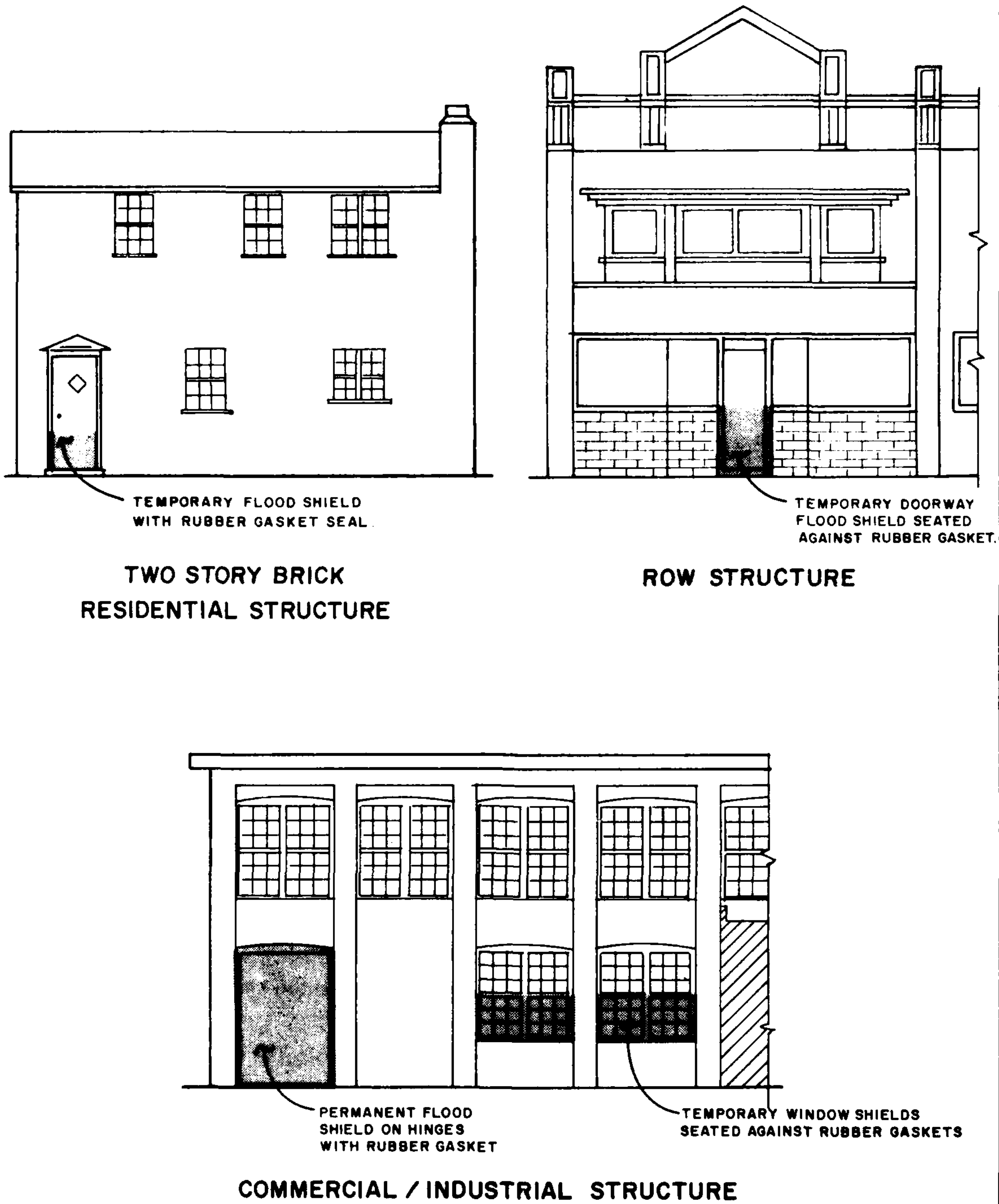

Figure 3-1. Temporary and Permanent Closures

Physical Feasibility

Most structures, whether residential, commercial or industrial, are not designed to withstand hydrostatic pressure on the exterior walls. The principal reason more structures do not collapse during flooding is that water enters the structure equalizing inside and outside pressures. If the objective is to prevent water from entering a structure it is imperative that the structure be analyzed to insure that it can withstand the pressures anticipated. Therefore when discussing physical feasibility the principal considerations are that 1), the exterior walls are impermeable or can be made so, 2) all openings below the design flood level can be closed, and 3) the structure can withstand the anticipated hydrostatic pressures including buoyancy.

Watertightness - Structures with exterior walls constructed of brick, brick veneer, concrete and cement block are relatively impermeable and can be made more so by sealing exterior surfaces. Similarly basement walls are usually of concrete or cement block and basement floors of concrete and therefore relatively impermeable. Structures of these types of materials are particularly suited to keeping out water and the only adjustments necessary is to minimize seepage through walls and floors with sealants and temporarily or permanently closing doorways and windows. Structures with sidings such as wood, aluminum, sheet metal, or masonite on either a wood or steel frame are generally permeable and difficult to keep water out. Similarly structures on raised foundations with wood flooring are much more permeable than concrete slab-on-grade.

Even for structures constructed of relatively impermeable materials the condition of the structure, and the number, location and size of openings influence the feasibility of providing closures. Masonry structures with extensive cracking or deteriorated materials may be little better than structures of permeable materials. Likewise, masonry structures with large and/or numerous openings lack the advantages associated with a structure with fewer openings. The most favorable condition for sealing and closing is a structure constructed of relatively impermeable materials, in good condition, and with few openings.

Structural Adequacy - Assuming a structure can be made to exclude water, the next consideration is for its structural adequacy. When water is prevented from entering a structure the walls become subject to lateral hydrostatic forces which may cause failure by bending or shear, and the floors to uplift forces which may cause buckling or flotation. In addition, dynamic forces may be present if the flow velocity is great. Most structures are not designed to carry these forces and consequently are in danger of collapse or floating if the flood water rises too high. It is particularly difficult to analyze the capability of existing structures to resist these forces because of the general lack of knowledge about workmanship and materials used during construction and about the present condition of these materials. Analyses can be made where assumptions are made regarding the design and materials used, but they are only valid where the conditions assumed do exist.

As part of this investigation structural analyses were made on the ability of walls and floors of various materials to withstand hydrostatic lateral and uplift pressures (6). Current construction practices for residential structures, new materials, and good workmanship were assumed. Generally these analyses confirmed analyses made by others (1, 2, 3) and are summarized below.

- Single and two story residential structures without basements, framed with wood with a partial brick or masonry siding, may float at depths of water less than 3 feet above the first floor.
- Single and two story residential structures without basements, constructed of brick or masonry with slab-on-grade may fail by buckling of the floor slab at depths of water of about 3 feet.
- Basements in single story brick or masonry structures may fail by flotation or buckling of the floor slab at depths of 4 feet above the basement floor if the soil becomes saturated. The validity of the assumption of soil saturation depends upon the duration of flooding, the type of soil, and the type of drainage system. Long duration flooding, permeable soil, and the absence of any drainage system around the walls or floor are all conducive to causing saturated conditions.
- Commercial and industrial structures are often constructed to take greater forces than residential structures and consequently can generally be expected to withstand greater hydrostatic pressures. Six feet of head is not unreasonable for many structures to effectively resist and it could be more.

Recent structural tests on a brick veneer wall (backed with wood framing) showed the wall failed with a head of less than 3 feet (4). Other analyses (1) on the design of basements for **new** structures recommended that water be allowed to enter the basement should it reach the basement window (about 5 feet above the basement floor). These analyses point to the limitations and potential hazards of keeping water out of residential type structures.

Costs

Base costs to provide temporary or permanent closures are the cost of the closures themselves and the cost of a sewer gate valve to prevent sewer backup. The cost of the closures depends principally upon the type closure selected. Only one sewer valve is generally required. An Engineer's estimate was made to provide these base cost items for a single or two story brick or masonry structure without basement. These costs are tabulated in Table 3-1. The estimated annual cost as a percentage of structure value is 0.34 percent.

TABLE 3-1

ESTIMATED COST FOR TEMPORARY CLOSURES[1]

Item		Estimated Cost
Flood Shields (3 - 3'x3' aluminum, installed)		$ 980.
Sewer Gate Valve		300.
Total First Cost	=	$1,280.
Annual Cost[2]	=	$ 102.
Annual Cost as Percentage of Structure Value	=	.34

[1] Estimated for a $30,000, 1,600 square foot structure with front, rear, and side entrances. Closure to 3 feet above first floor. Costs include 25 percent for contractor's bonds, overhead, profit and engineering.

[2] Amortized at 7 percent for 30 years.

Other cost items sometimes required to insure watertightness are,

- Sealant for exterior walls including sand blasting, caulking cracks, applying sealant, and repainting.
- Wall construction around a patio to protect sliding glass doors.
- Fireplace cleanout seal.
- Flood shields for additional doors or windows.
- Inspection to insure watertightness over the life of the structure.

More and larger openings or additional protection (sealants, etc.) will increase the base cost shown in Table 3-1.

Economic Feasibility

When flood water is prevented from entering a structure, damage is reduced up to the design level. When a flood exceeds the protection level damage occurs as it normally would without protection and immediate inundation to that level is normally assumed. Damage reduced includes damage to contents and structure interior. Damage to the structure exterior and the site still remain. Figures 3-2 and 3-3 show expected annual damage reduced by protecting a single or two story structure without basement to 3 feet above the first floor. The values include a reduction in damage to the structure exterior, but this is small. Details of this analysis are discussed in Appendix A.

These data show damage reduced varies from over 14 percent to approximately 0.25 percent of the structure value depending upon the type structure, flood hazard factor, and event at the first floor. This compares with an estimated cost of 0.34 percent discussed in the previous section. This cost is shown in the Figures for comparison with damage reduced. For a single story, no basement structure (Figure 3-2) damage reduced exceeds costs for all conditions

shown. This indicates that protecting to 3 feet above the first floor will generally be economically feasible for this type structure. Naturally, if significant additional cost are incurred above those assumed, it may become infeasible. A two story, no basement structure (Figure 3-3) shows damage reduced roughly 50 percent of that for a single story structure. This reduction causes economic feasibility to be somewhat marginal for conditions with a flood hazard factor of twelve or greater and located with the 20 year event at the first floor. Because of the closeness of the values in this range it is difficult to draw definite conclusions from the analyses since a change of any one of several factors could make up the difference.

Advantages and Disadvantages

Table 3-2 summarizes the advantages and disadvantages of this measure as an adjustment tool.

TABLE 3-2

ADVANTAGES AND DISADVANTAGES OF TEMPORARY OR PERMANENT CLOSURES FOR EXISTING STRUCTURES

Advantages	Disadvantages
Flood proofing may be done on a selective basis to only those openings through which water enters and only to the height desired.	Applicable only to structures with brick or masonry type walls, without basements, which can structurally withstand the hydrostatic and uplift pressure of the design flood and which are generally watertight.
Easy and quick to implement.	Reduced likelihood of effective closure at nights and during vacations with temporary closures.
For large commercial and industrial type structures, this may be the most important nonstructural means of flood damage reduction.	May create a false sense of security and induce people to stay in the structure longer than they should.

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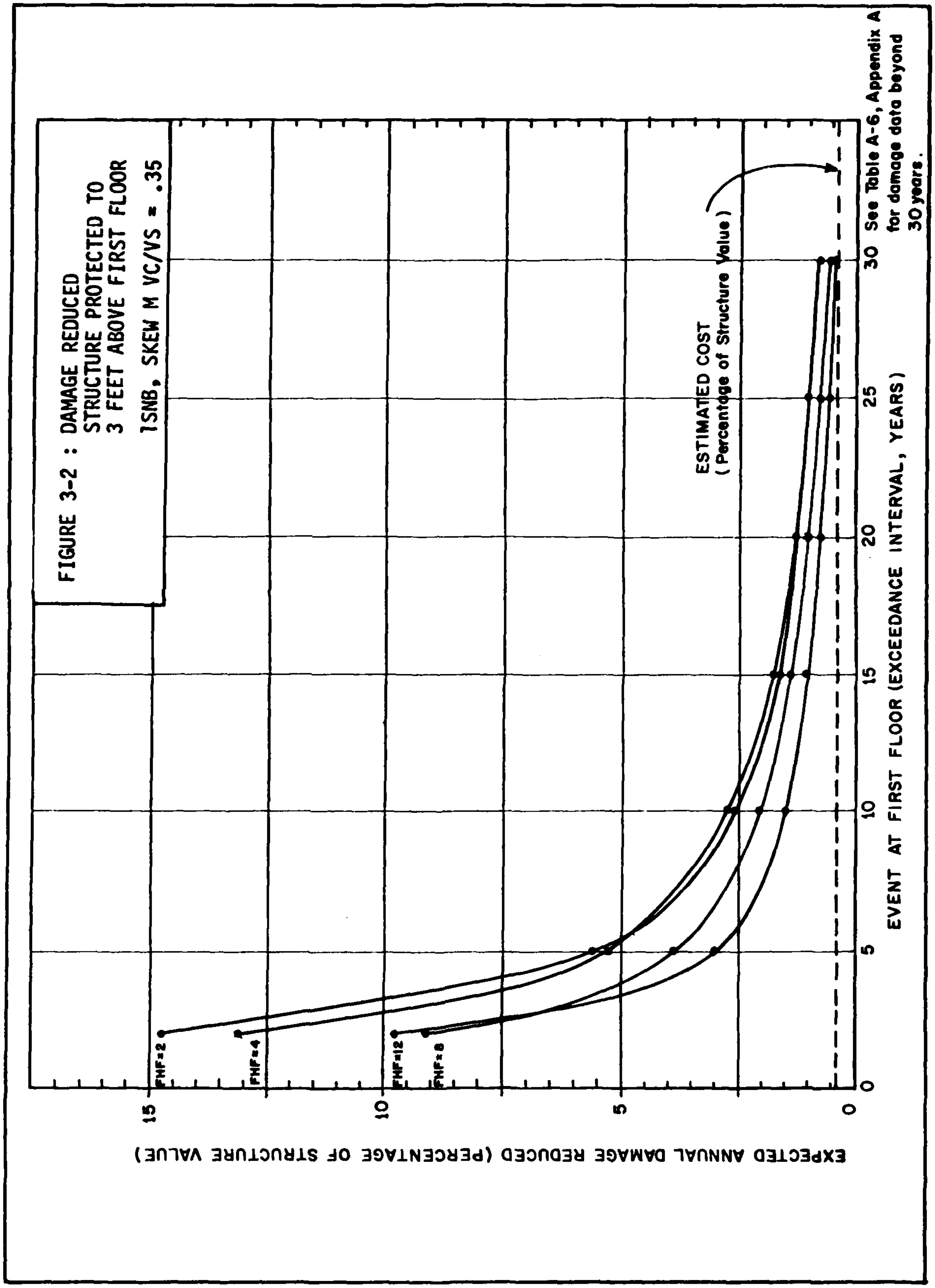


FIGURE 3-2 : DAMAGE REDUCED
STRUCTURE PROTECTED TO
3 FEET ABOVE FIRST FLOOR
ISNB, SKEW M VC/VS = .35
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)
ESTIMATED COST
(Percentage of Structure Value)
See Table A-6, Appendix A
for damage data beyond
30 years.
FHF=2
FHF=4
FHF=12
FHF=8
0
5
10
15
20
25
30

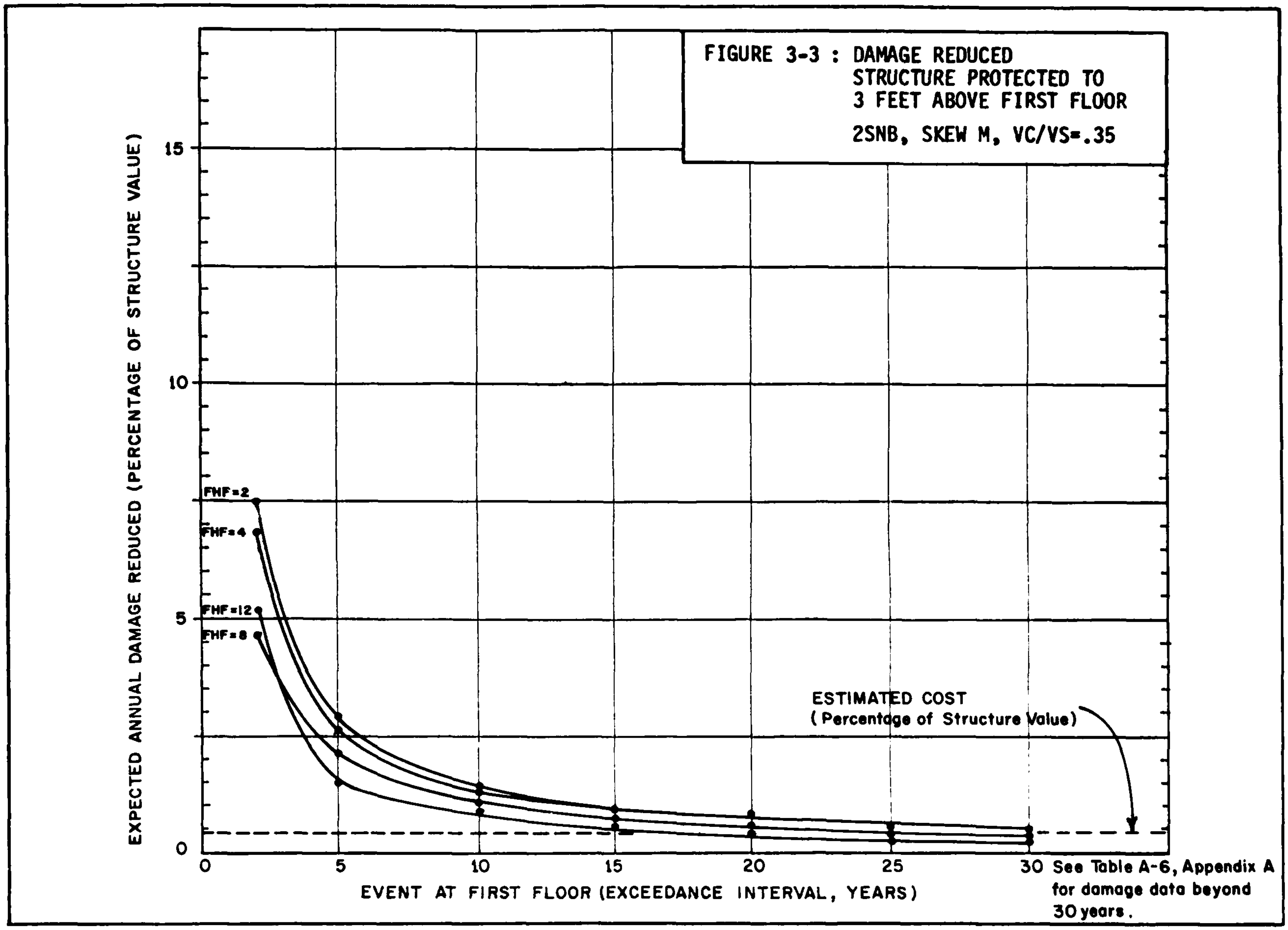


FIGURE 3-3 : DAMAGE REDUCED
STRUCTURE PROTECTED TO
3 FEET ABOVE FIRST FLOOR
2SNB, SKEW M, VC/VS=.35
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
0
5
10
15
FHF=2
FHF=4
FHF=12
FHF=8
ESTIMATED COST
(Percentage of Structure Value)
0
5
10
15
20
25
30
See Table A-6, Appendix A for damage data beyond 30 years.
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)

CHAPTER 4

RAISING EXISTING STRUCTURES

Description

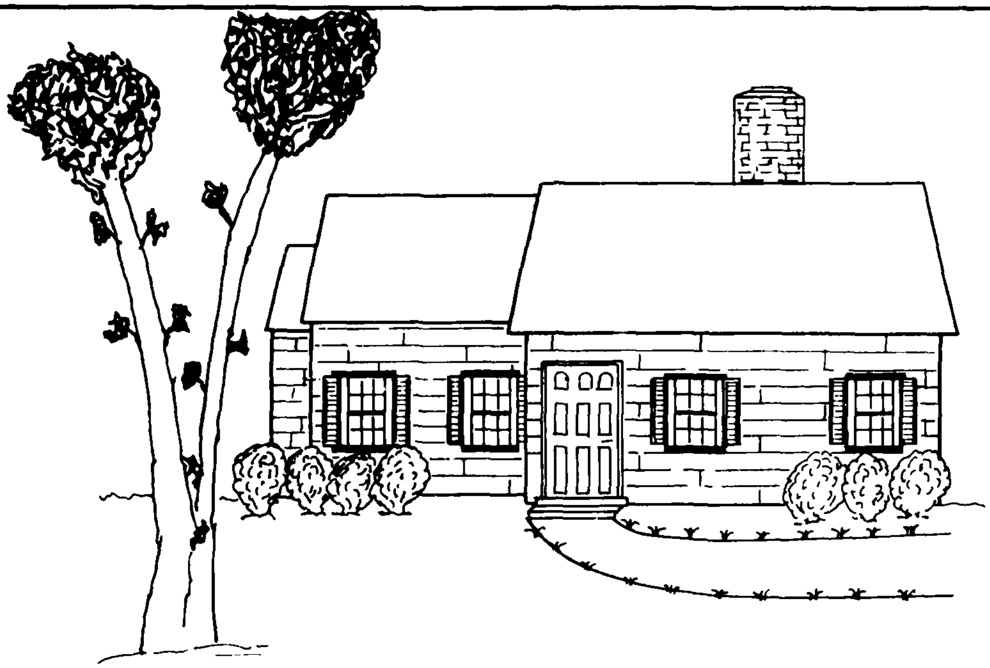
Existing structures in flood hazard areas can often be raised in-place to a higher elevation to reduce the susceptibility of the structure to flood damage. Specific actions required to raise a structure include,

- Disconnect all plumbing, wiring, and utilities which cannot be raised with the structure.
- Place steel beams and hydraulic jacks beneath the structure and raise to desired elevation.
- Extend existing foundation walls and piers or construct new foundation.
- Lower the structure onto the extended or new foundation.
- Adjust walks, steps, ramps, plumbing, and utilities and regrade site as desired.
- Reconnect all plumbing, wiring and utilities.
- Insulate exposed floors to reduce heat loss and protect plumbing, wiring, utilities and insulation from possible water damage.

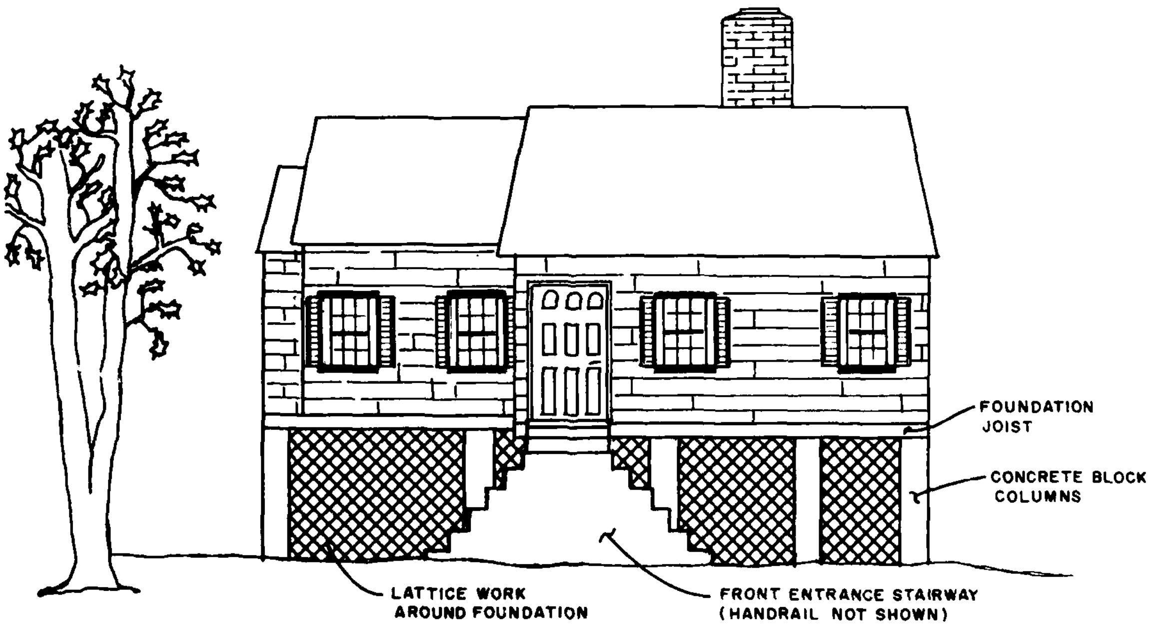
These actions are intended to place the structure at a higher elevation at its existing site and to protect plumbing and utilities below the first floor from water damage. Because the hazard is not eliminated, but only the damage potential reduced, it is important that the potential for flooding below the first floor be recognized in the raising. Where wave action is likely, the structure should be raised an additional height above the design level to prevent inundation by waves. Lateral stability of the structure should be insured by designing the foundation walls or piers in a way that a hinge effect is not created between the superstructure and foundation. Also, flood flow velocity should be accounted for in the design. All ground to house utility lines (sewer, electrical, gas, water, telephone) should be protected against water, wind and extreme temperature exposure which may be brought about by elevating the structure. Access to and from the structure during high water should be insured when raising walks, steps, ramps, and when regrading the site. This is important to insure occupant safety in the event the design flood is exceeded. Figure 4-1 illustrates the concept of raising in-place.

Physical Feasibility

The principal consideration for physical feasibility is that the structure can be raised economically. Generally, the technology exists to raise almost any structure, even multistory buildings, however, the more difficult the raising the more costly it becomes. Within the normal range of expected annual flood damage, raising-in-place from a practical viewpoint is most applicable to structures which can be raised with low cost conventional means. Generally, this means structures, 1) which are accessible below the first floor for placement of jacks and beams, 2) which are light enough to be jacked with conventional house moving equipment, and 3) which are small enough that they do not have to be partitioned. Wood frame residential and light commercial structures with first floors above the ground (normally with an 18" crawl space beneath the first floor) are particularly suited for raising. Wood frame structures with basements below the first floor are also accessible and light weight, however, raising the superstructure



RESIDENCE BEFORE RAISING



RESIDENCE AFTER RAISING

Figure 4-1. Raising Existing Structure
(Adapted from Reference 1)

does not protect the basement and it is doubtful many basement walls or floors could be reinforced to take the hydrostatic head economically. A more likely approach if it were necessary to raise a structure with basement would be to minimize the damageable property in the basement and allow flooding. Brick, brick veneer, and masonry structures, while heavier and more difficult to handle can also be raised. Structures with concrete slab floors on the ground (slab-on-grade) and structures with common walls (row structures) are not feasible to raise without special equipment and additional expense. While it is physically possible to raise many types of structures, it is often not practical for the reasons mentioned above. Where raising in-place is in fact being done it seems to be principally to wood frame type structures on raised foundations (no basement).

As to height of raising, residential structures have been satisfactorily raised up to nine feet (1). Aesthetics, intended use, 100 year flood elevation and structural stability are factors which often influence the height selected. Generally the additional cost to raise a structure an additional foot or so is small compared to the initial set-up cost.

Costs

Base cost items to raise a structure in-place include,

- Brace, jack, and reset structure (including disconnecting utilities and temporary connections).
- Extend existing or construct new foundations.
- Extend and reconnect all utilities.
- Reconstruct walks, steps, ramps.
- Relandscape site (including plant replacement and siding).
- Architectural/Engineering fees.

Additional cost items may be applicable depending upon the specific site conditions. Examples of these items include,

- Removal and disposal of sidewalks, curbs, ramps, driveways not used in the reconstruction.
- Updating structure foundation and utilities to code.
- Additional bracing for stucco, or brick sidings or structures in poor condition.
- Reconstruction of chimney and fireplace.
- Temporary housing during raising.
- Additional aesthetic work.

Engineer's cost estimates were made for raising a 1600 square foot structure without basement, on a raised foundation, three feet. These data are summarized in Table 4-1. Only base cost items were included so the estimate would represent a minimum cost. The Table shows a total estimated first cost of $7,750, and an annual cost of $621. As a percentage of total structure value for a $30,000 structure the annual cost is 2.1 percent. Lesser valued structures may cost less to raise, either because they are of smaller size, or simpler architecturally. However, because they are of lesser value the lower cost may be offset and the percentage remain the same.

Greater valued structures are likely to require additional landscape and aesthetic work to make them compatible with the site. In this situation, increased costs may be offset by increased value and the percentage may not be too different.

TABLE 4-1

ESTIMATED COST TO RAISE AN EXISTING STRUCTURE IN-PLACE[1]

Item		Estimated Cost
Brace and Load Structure • Disconnect, reconnect utilities		$3,200.
Extend Existing Foundation		2,500.
Reconstruct Porches, Ramps and Stairs, Relandscape		2,050.
Total First Cost	=	$7,750.
Annual Cost[2]	=	$ 621.
Annual Cost as Percent of Structure Value	=	2.1

[1] Estimated for a 1,600 square foot, $30,000 structure without basement, on raised foundation. Height raised assumed to be 3 feet. Costs include 25 percent for contractor's bonds, overhead, profit, and engineering.

[2] Amortized at 7 percent for 30 years.

Economic Feasibility

Raising a structure without basement reduces damage caused by flood events below the raised first floor elevation. Residual damage still remains for flood events above the raised first floor elevation and some minor damage may occur to the underside of the first floor flooring. Analysis of damage reduced by raising a structure three feet and five feet was made in Appendix A. Results of this analysis are presented in Figures 4-2 through 4-5. A structure was assumed to be raised three and five feet for the conditions indicated and zero damage was assumed to occur below the first floor. Damage reduced was computed as the difference in expected annual damage with and without the structure raised. The curves show considerable variability depending on the type structure and event at the first floor.

An estimate of economic feasibility was made by plotting the estimated cost of raising a structure three feet and five feet on the respective Figures.

The estimated minimum cost for raising a structure three feet was 2.1 percent from Table 4-1. It was assumed the cost to raise a structure five feet would be 25 percent more or approximately 2.6 percent. When compared with expected annual damage reduced these data indicate that for one story, no basement structures, raising a structure three feet or five feet is generally feasible below the 10 year flood plain, not likely to be feasible above the 15 year flood plain, and

questionable in the 10 to 15 year range. For a two story structure without basement, raising three feet or five feet generally appears feasible below the 7 year flood plain, not feasible above the 10 year, and questionable between the 7 to 10 year flood plains. Because the cost data intersects the damage reduced functions where they are generally at a moderate slope the general feasibility conclusions stated above are not particularly sensitive to changes in cost. For example, a 50 percent increase in cost would only change the flood plains indicated by three years or so.

Advantages and Disadvantages

Table 4-2 below summarizes the advantages and disadvantages of raising a structure in-place.

TABLE 4-2

ADVANTAGES AND DISADVANTAGES OF RAISING AN EXISTING STRUCTURE

Advantages	Disadvantages
Damage to structure and contents is reduced for floods below the raised first floor elevation.	Residual damages exist when floods exceed the raised first floor elevation. Minor damage may occur below the first floor depending upon use.
Particularly applicable to single and two story frame structures on raised foundations.	Not generally feasible for structures with slab-on-grade foundations or structures with basements (unless basement flooding is tolerated).
Structures have been raised to heights up to nine feet. The greater heights are probably most acceptable in wooded areas of steep topography.	Landscaping and terracing may be necessary if the height raised is extensive.
The means of raising a structure are well known and contractors are readily available.	
Raising in-place allows the user/owner to continue operations at the existing location.	
Flood insurance premiums are reduced.	

References

1. U.S. Army Engineers, "Flood Proofing: Example of Raising a Private Residence", South Atlantic Division, Technical Services Report, March 1977.

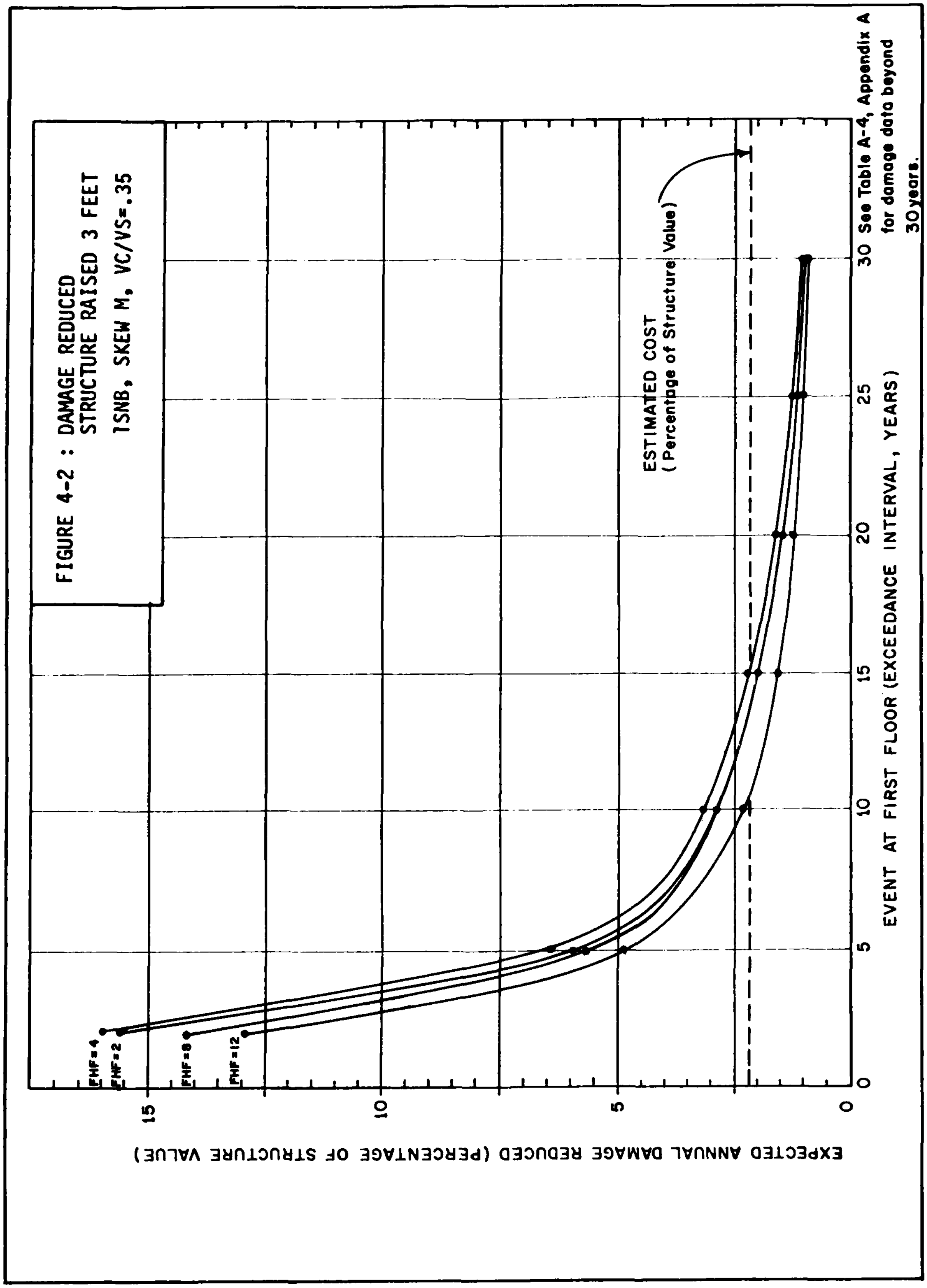


FIGURE 4-2 : DAMAGE REDUCED
STRUCTURE RAISED 3 FEET
1SNB, SKEW M, VC/VS=.35

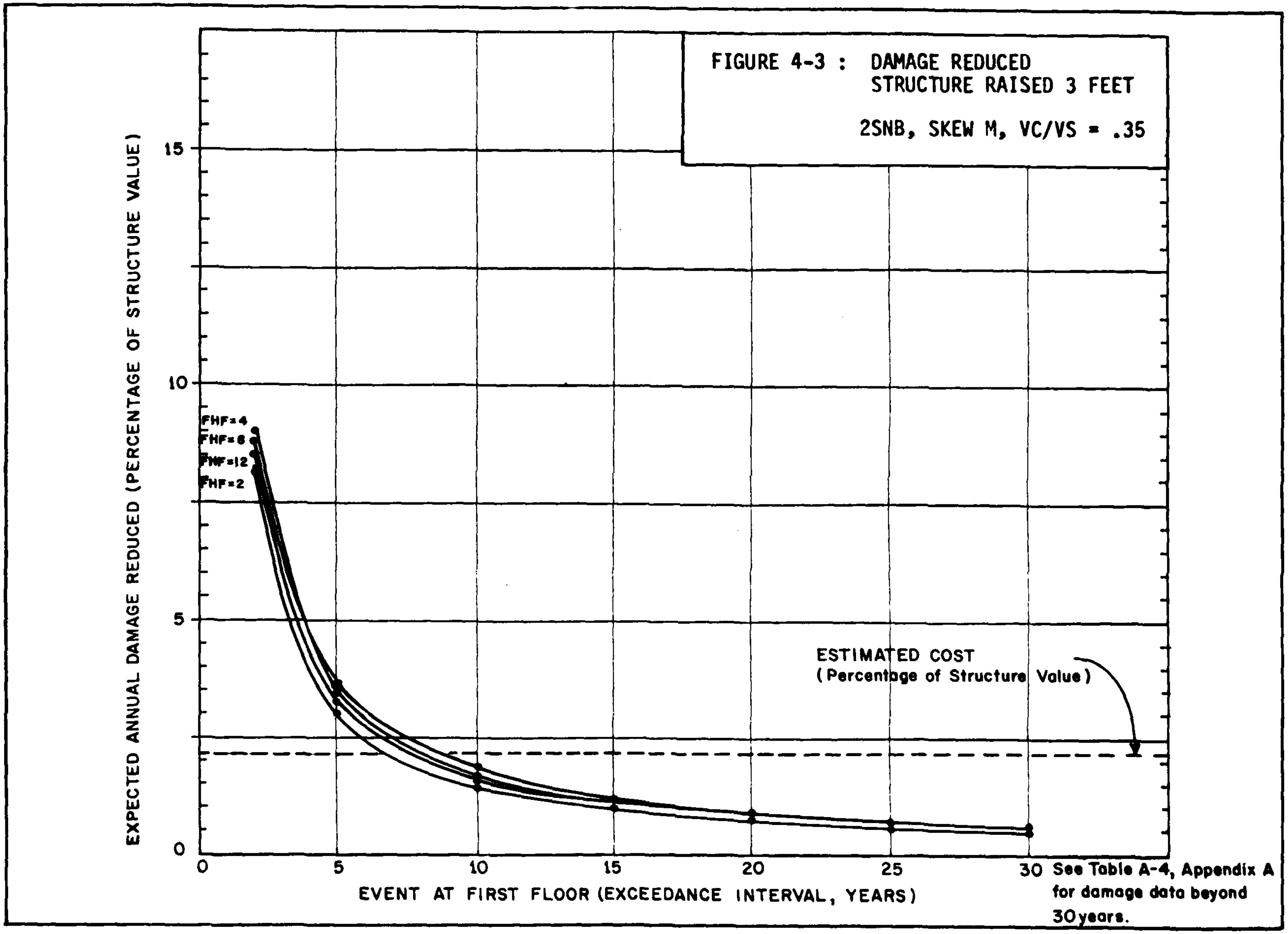


FIGURE 4-3 : DAMAGE REDUCED
STRUCTURE RAISED 3 FEET
2SNB, SKEW M, VC/VS = .35
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)
FHF=4
FHF=8
FHF=12
FHF=2
ESTIMATED COST
(Percentage of Structure Value)
See Table A-4, Appendix A for damage data beyond 30 years.

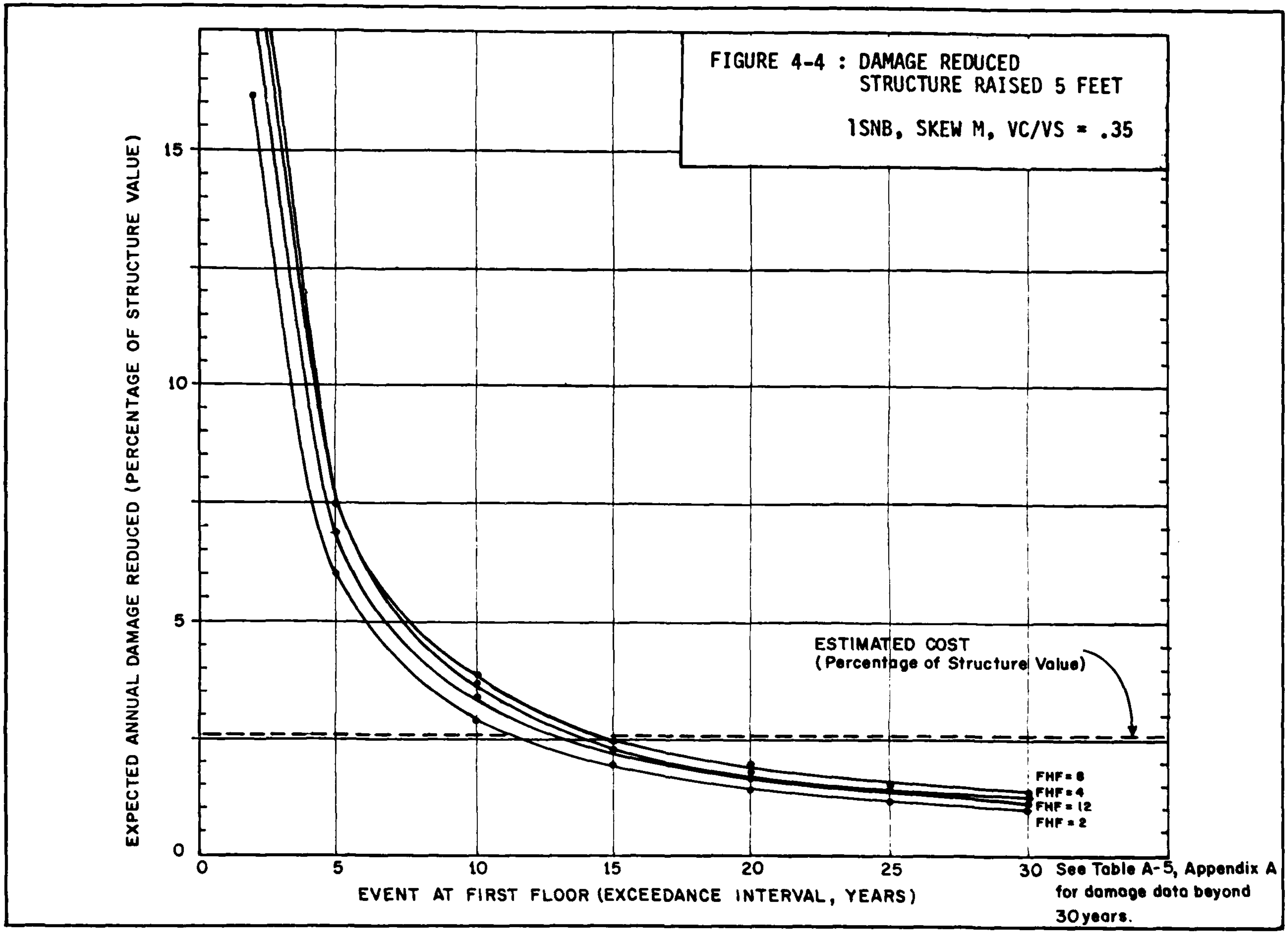


FIGURE 4-4 : DAMAGE REDUCED
STRUCTURE RAISED 5 FEET

1SNB, SKEW M, VC/VS = .35

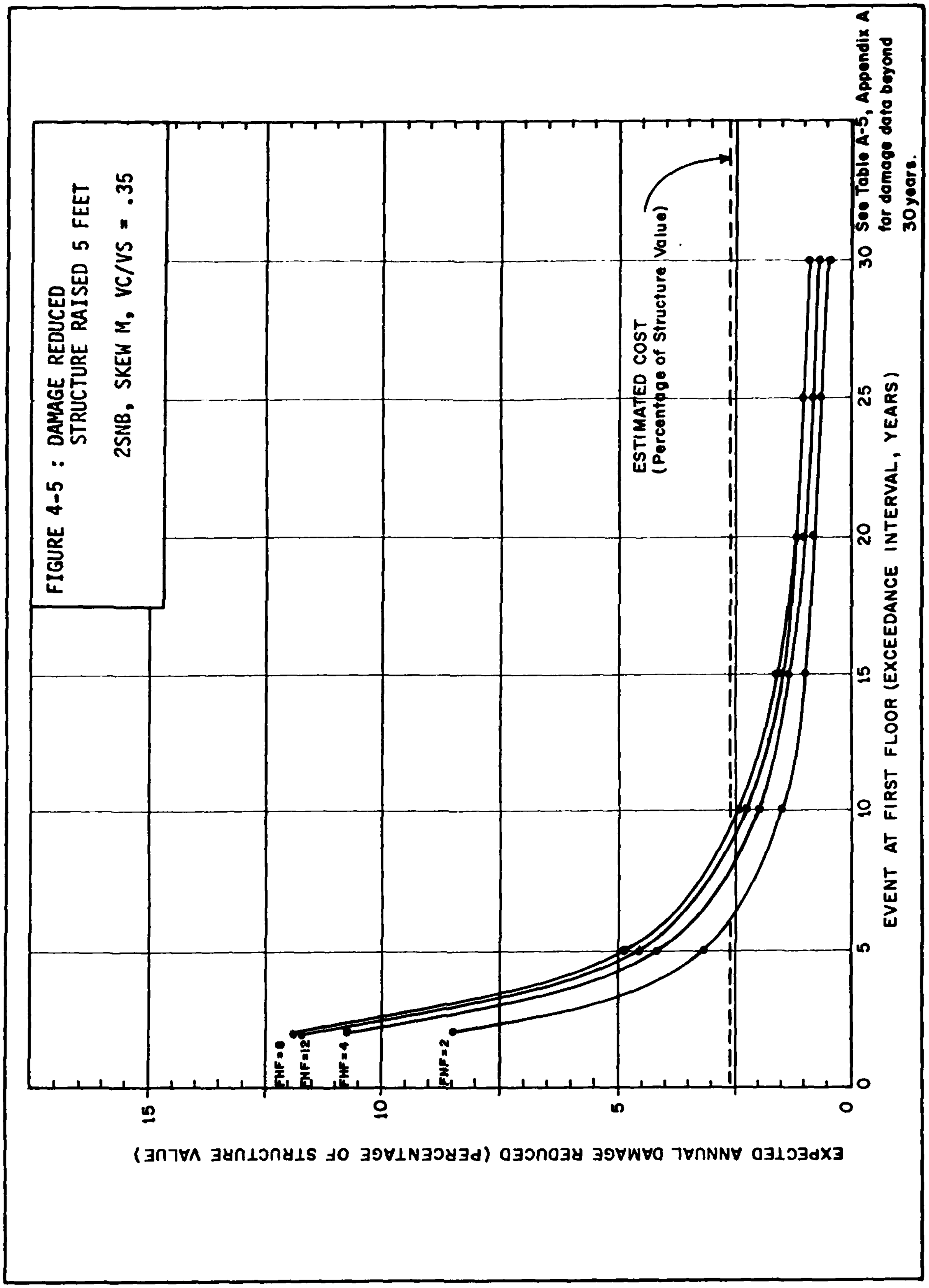


FIGURE 4-5 : DAMAGE REDUCED STRUCTURE RAISED 5 FEET

2SNB, SKEW M, VC/VS = .35

CHAPTER 5

SMALL WALLS OR LEVEES AROUND NEW OR EXISTING STRUCTURES

Description

Flood walls and levees along rivers and streams have been used for centuries to exclude water from flood plain land. Often they extend for miles along a river. In the context of nonstructural measures a much more local use is intended. Wall and levee heights are generally less than six feet, they are designed to protect one or several structures, and they are built to be compatible with local landscape and aesthetics. Walls may be of brick, stone, concrete or other material designed to resist the lateral and uplift pressures associated with flooding. In urban areas where space is limited, walls running along property lines may be low (3 feet) so as not to hide store fronts, or high (6 feet) to create patio or garden areas for apartments or townhouses. On suburban sites a wall may be attached to a structure, for example, by running along a porch, or detached and located at the property line as a fence. Levees are usually constructed with an impervious inner core to prevent seepage and with slope protection if erosion is a problem. Serpentine levees along the backside of a lot can be designed to be compatible with many landscapes and at the same time serve to exclude flood waters.

Where access openings are necessary, provisions must be made to close these openings during floods. This generally means providing a flood gate which can either be stored at the opening and installed when needed, or constructing it on hinges or rollers for automatic or semi-automatic closure. A watertight seal is formed by use of a rubber gasket between the shield or gate and opening frame.

During flood conditions it is possible for precipitation, seepage, and runoff from roof drains to cause water to accumulate inside a wall or levee and cause water damage to the property being protected. This problem can be reduced by providing interior drainage facilities to remove the water. Generally this includes a low lying sump area to collect the drainage and a pump to remove it. The pump discharge level should be located above the design flood level. The capacity pump required will depend upon the interior storage, site grading, lift, and rainfall intensity anticipated. As part of interior drainage, sewer backup can be prevented by installing a gate valve in the line.

Figure 5-1 illustrates the adjustments associated with this protection measure and Reference 1 contains examples of its use.

Physical Feasibility

One particular advantage of a wall or levee is that it is not limited to a particular type or size of structure and therefore is feasible for any residential, commercial or industrial building. The question of physical feasibility centers more on site conditions; topography, available space, compatibility with existing use, soil and ground water conditions; and on the nature of flooding velocity and location relative to the structure, depth, and warning time. Both walls and levees offer considerable flexibility in design to make them compatible with both site and use: Wall and levee heights can vary, natural land topography can be followed, walls can be constructed

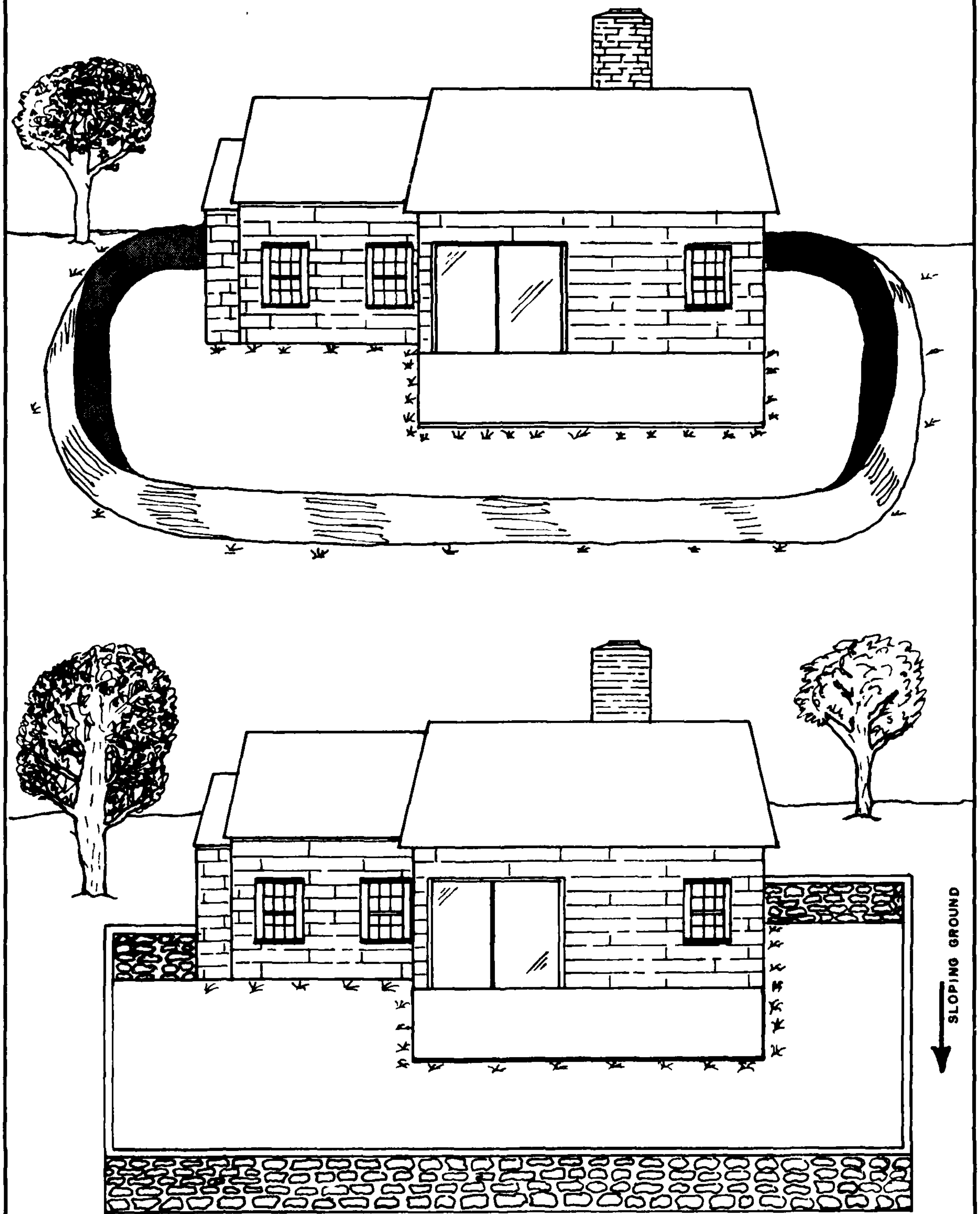


Figure 5-1. Small Walls or Levees

of attractive building materials, and levees landscaped. Soil conditions must be capable of supporting loads transmitted to the foundation. While both walls and levees can be designed for marginal soil conditions, the cost of such measures may be prohibitive.

The nature of flooding is important in determining feasibility in several ways. High velocity flows cause erosion which could endanger a wall or levee unless protected, and erosion protection adds to the cost. In addition, velocity adds a dynamic pressure to the design which may further increase cost. The location of flood waters relative to the structure is also important. If only the backside of a structure need be protected the selection of means and number of openings required may be different than if the entire structure or front is protected. When the depth of flooding is greater than that for which protection can be provided it precludes use of the measure or requires adopting a different level of protection. This, of course, is true of any flood proofing measure. Generally, for a small wall or levee, six feet is the practical limit although designs are feasible for greater heights. If access openings are necessary automatic closures should be used or ample warning time should be available to install shields and gates. Warning times vary greatly for different hydrologic and local community conditions. Both daytime and nighttime operation should be planned for when selecting the method of closure.

Costs

The principal base cost items for small walls and levees are,

- Construction of wall or levee.
- Drainage for the interior, enclosed area.
- Protection against sewer back-up.

The principal variables in estimating the costs of the first item is the length and height of wall or levee. Generally, the nature of the flood hazard will determine the length and height. Structures built on topography sloping up from a river or creek can often be protected by providing a wall or levee on the backside only. Costs in this situation will be considerably less than if the entire structure must be protected. Interior drainage can usually be handled by installing a sump pump and sewer backup by a gate valve. Engineer's estimates of these basic cost items are presented in Table 5-1. For a $30,000 structure the costs as a percentage of structure value range from 0.5 to 1.6 percent depending upon whether a wall or levee is used and its height.

TABLE 5-1

ESTIMATED COST TO PROTECT A STRUCTURE WITH A SMALL WALL OR LEVEE[1]

Item	Estimated Cost			
	Wall		Levee	
	3 Feet	5 Feet	3 Feet	5 Feet
Construct Wall or Levee	$3220.	$4900.	$ 800.	$1600.
Provide Sump Pump	950.	950.	950.	950.
Install Sewer Gate Valve	300.	300.	300.	300.
Total First Cost	$4470.	$6150.	$2050.	$2850.
Annual Cost[2]	$ 358.	$ 493.	$ 164.	$ 228.
Annual Cost as Percentage of Structure Value	1.2	1.6	.5	.7

[1] Estimated for a 1600 square foot, $30,000 structure with or without basement. Protection assumed along backside of lot—140 feet for a wall and 216 feet for a levee. Costs include 25 percent for contractor's bonds, overhead, profit, and engineering.

[2] Amortized at 7 percent for 30 years.

There can be other cost items associated with these measures depending upon specific site requirements. These items include,

- Access closures for walkways and driveways.
- Relandscaping lot for aesthetic and/or interior drainage.
- Decorative stone or brick for walls and plantings for levees.
- Maintainence of wall or levee in water tight condition.
- Levee erosion protection.
- Power used for pumping.
- Removal and replacement of walkways, driveways or patios to accommodate a wall or levee.

Economic Feasibility

A small wall or levee if constructed away from the structure will prevent damage to both structure and contents. Damage is prevented up to its design height. If its level of protection is exceeded, immediate inundation is usually assumed and damage occurs to that level. Damage reduced is measured as the difference in damage with and without the wall or levee. Detailed analysis of damage reduced by providing three foot and five foot protection to one and two story structures with and without basements is discussed in Appendix A. Figures 5-2 through 5-9 show the results of these analyses.

Economic feasibility was estimated by plotting the minimum cost estimates presented in Table 5-1 on each Figure. The cost for a three foot wall and levee was 1.2 and 0.5 percent respectively (expressed as a percentage of structure value). A five foot wall or levee was estimated to cost 1.6 and 0.7 percent respectively. A comparison of minimum cost and damage reduced shows a small levee (three feet and five feet) to be economically feasible for all flood hazard factors, all locations in the flood plain, and all type structures except a two story, no basement structure. For this latter structure a three foot levee appears to be feasible below the 15 year flood plain and a five foot levee below the 20 year flood plain (see Figures 5-3 and 5-7). Above these locations feasibility depends upon the event at the first floor and flood hazard factor.

A small wall, because of its higher cost is somewhat less feasible. Protection of a one story, no basement structure appears to be feasible for both a three foot and five foot height below about the 15 year flood plain, infeasible above the 25 year and questionable between the two. See Figures 5-2 and 5-6. A two story, no basement structure appears feasible below about the 7 year, infeasible above about the 15 year and questionable between the 7 and 15 year events at the first floor. This is illustrated in Figures 5-3 and 5-7. Three foot and five foot walls are generally economically feasible for one and two story structures with basements at any location in the flood plain provided the flood hazard factor is less than about 8.0 feet. For higher flood hazard factors economic feasibility varies with type structure, height of protection and location in flood plain.

Advantages and Disadvantages

Table 5-2 summarizes several advantages and disadvantages of small walls or levees.

TABLE 5-2

ADVANTAGES AND DISADVANTAGES OF PROTECTING A NEW OR EXISTING STRUCTURE WITH A SMALL WALL OR LEVEE

Advantages	Disadvantages
Not dependent upon the size, type, or condition of property being protected.	Dependent upon site conditions: Topography, property lines, available space, soil and ground water conditions, velocity and depth of flooding, and location of flood water relative to structure.
Protects property outside a structure.	May require access openings which must be closed during a flood. If the closures are manual a warning time is necessary.
Can be aesthetically pleasing and provide privacy and security in addition to flood protection.	

References

1. Dexter, James, "Planning a Program for Flood-Proofing Technology Transfer to Flood-Plain Residents", Ph.d. Dissertation, Department of Civil Engineering, Georgia Institute of Technology, 1977.

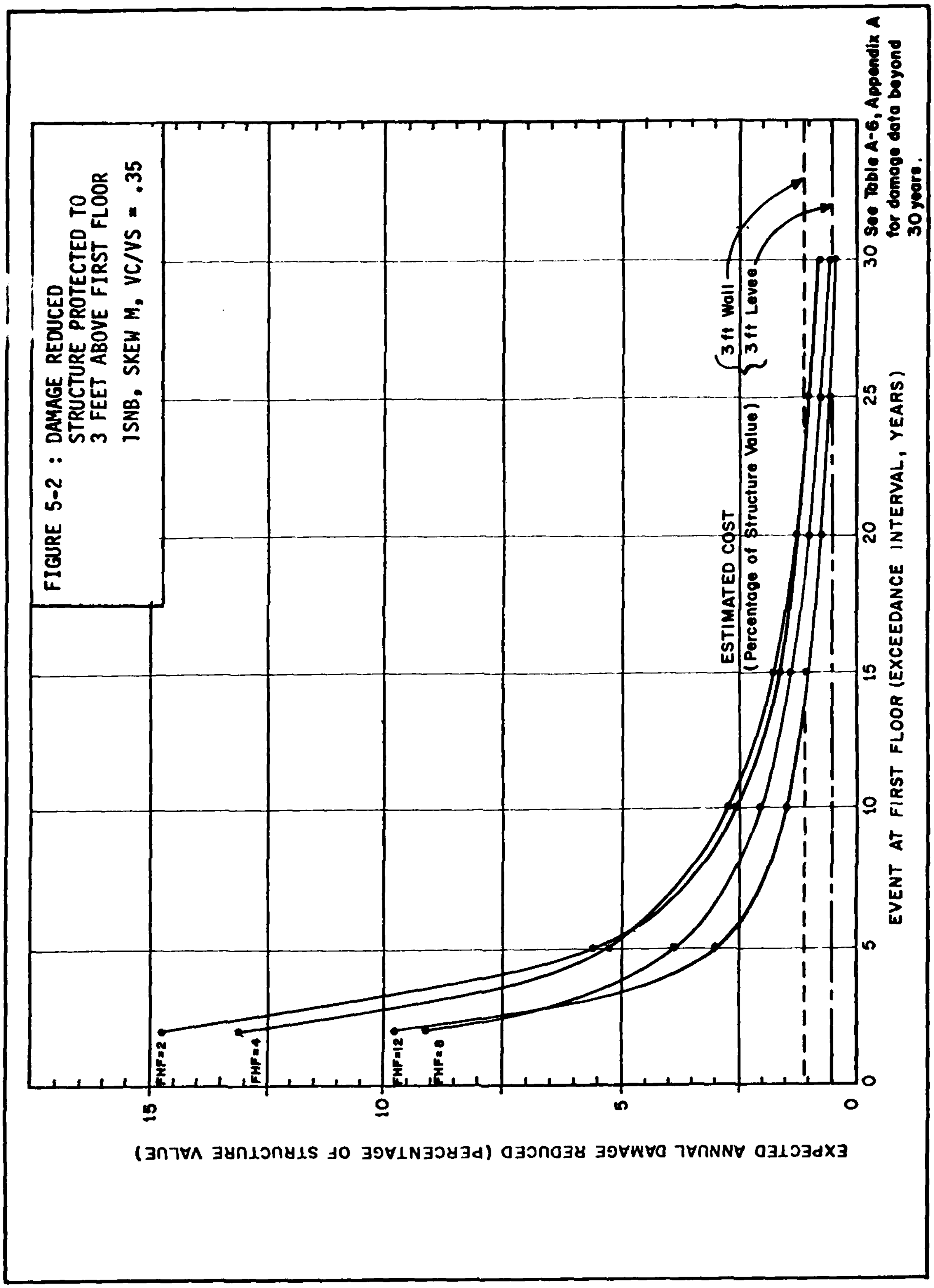


FIGURE 5-2 : DAMAGE REDUCED STRUCTURE PROTECTED TO 3 FEET ABOVE FIRST FLOOR

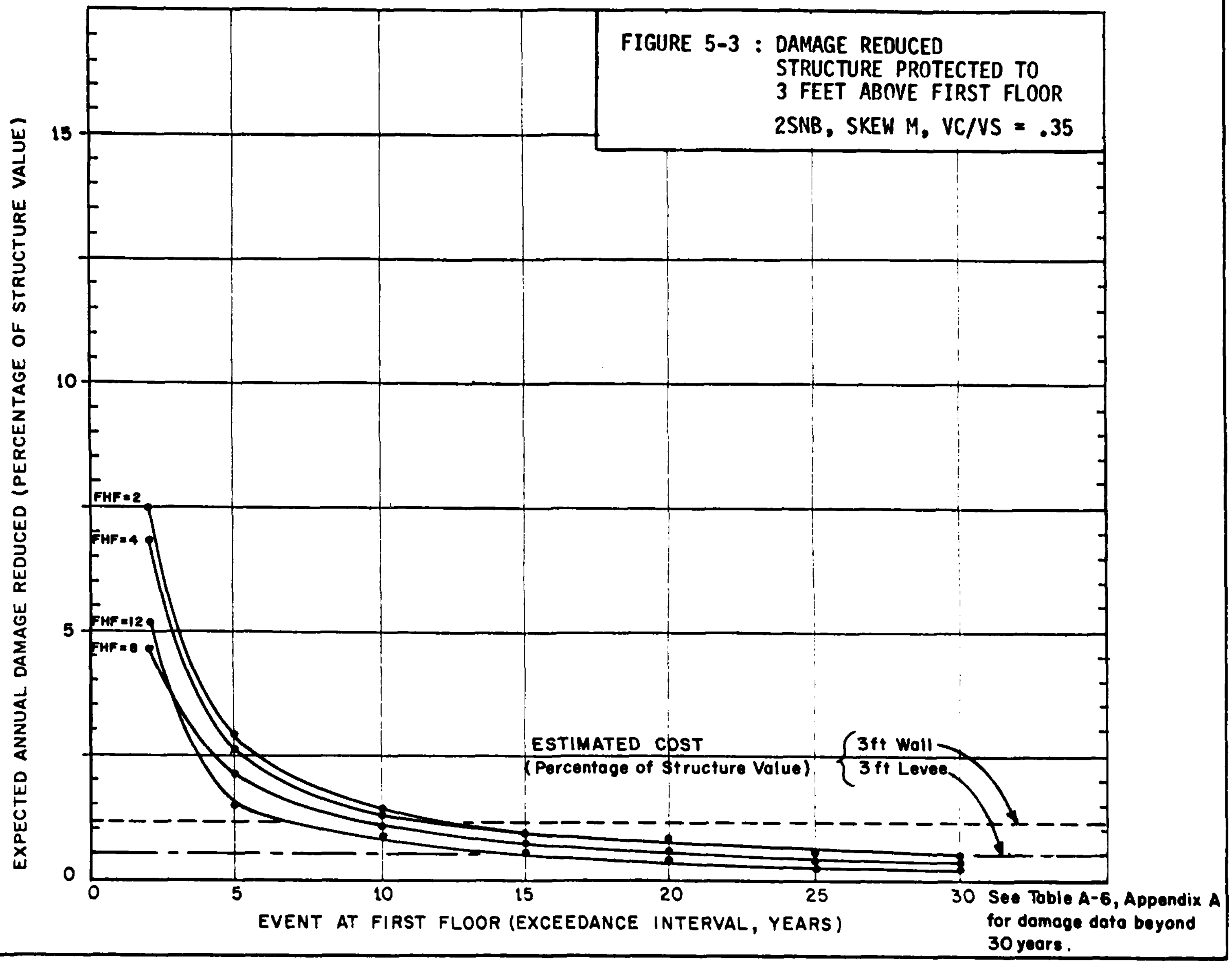


FIGURE 5-3 : DAMAGE REDUCED STRUCTURE PROTECTED TO 3 FEET ABOVE FIRST FLOOR

2SNB, SKEW M, VC/VS = .35

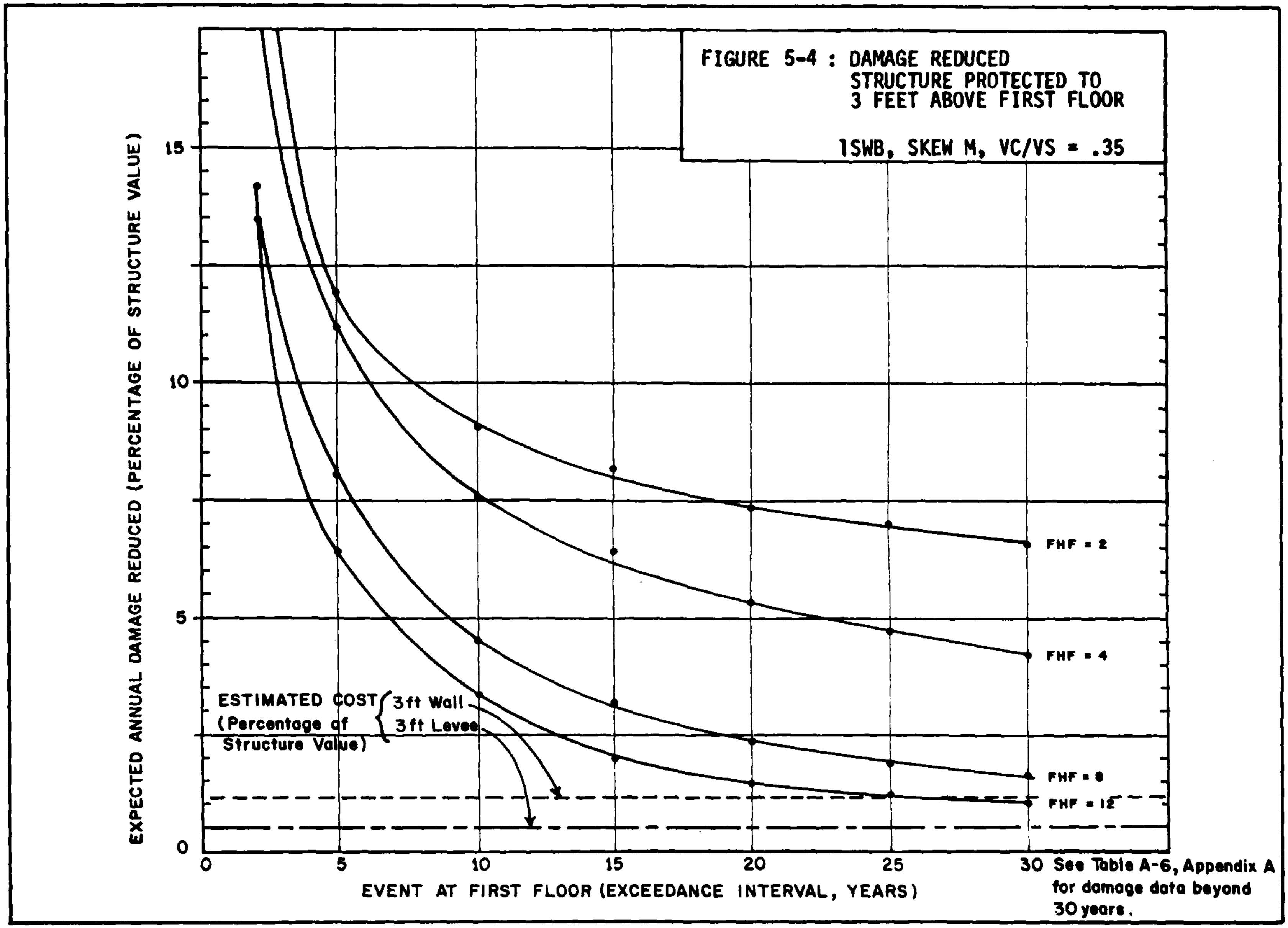


FIGURE 5-4 : DAMAGE REDUCED
STRUCTURE PROTECTED TO
3 FEET ABOVE FIRST FLOOR
1SWB, SKEW M, VC/VS = .35
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)
0
5
10
15
20
25
30
FHF = 2
FHF = 4
FHF = 8
FHF = 12
ESTIMATED COST (Percentage of Structure Value)
3 ft Wall
3 ft Levee
See Table A-6, Appendix A for damage data beyond 30 years.

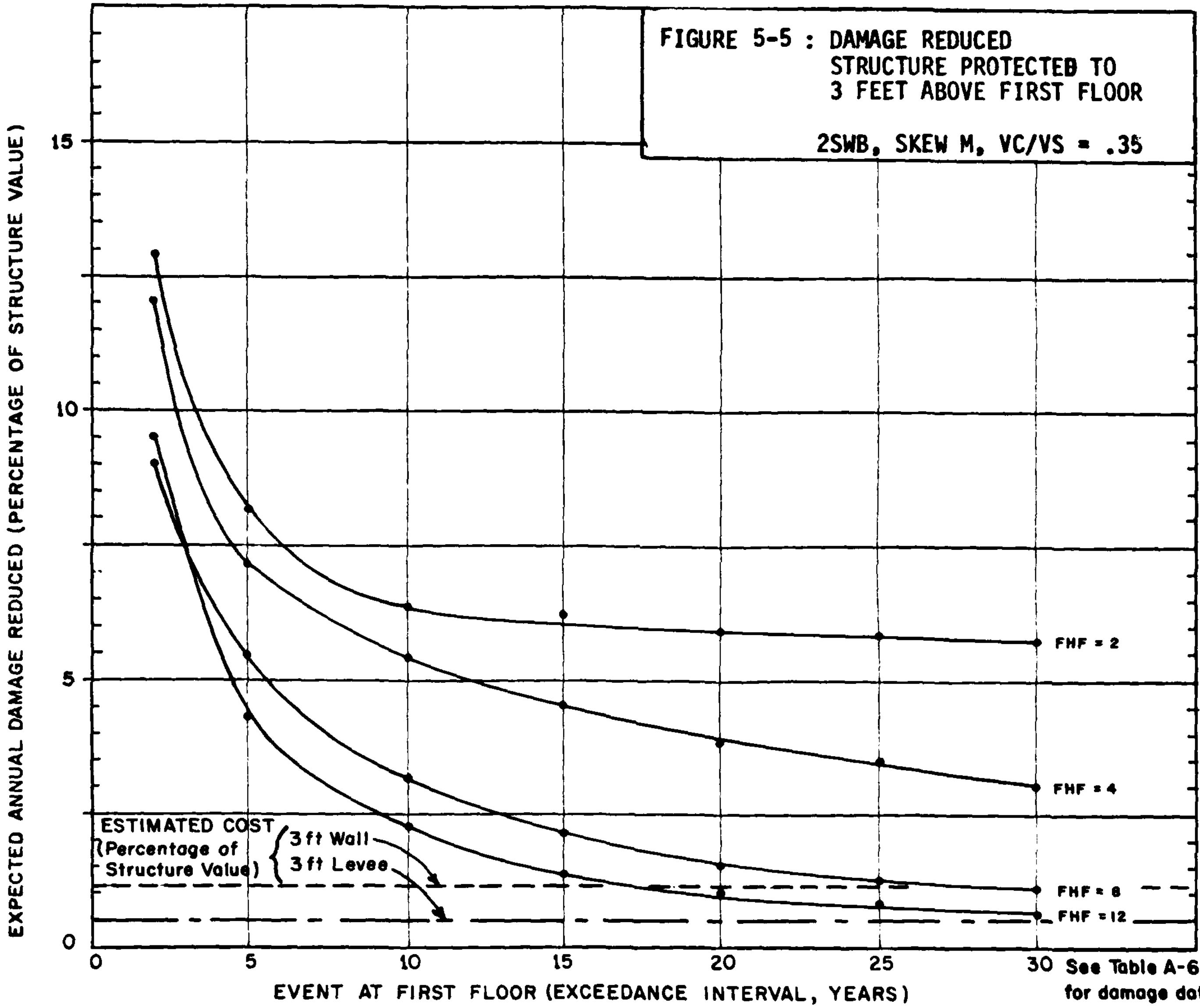


FIGURE 5-5 : DAMAGE REDUCED STRUCTURE PROTECTEB TO 3 FEET ABOVE FIRST FLOOR

2SWB, SKEW M, VC/VS = .35

See Table A-6, Appendix A for damage data beyond 30 years.

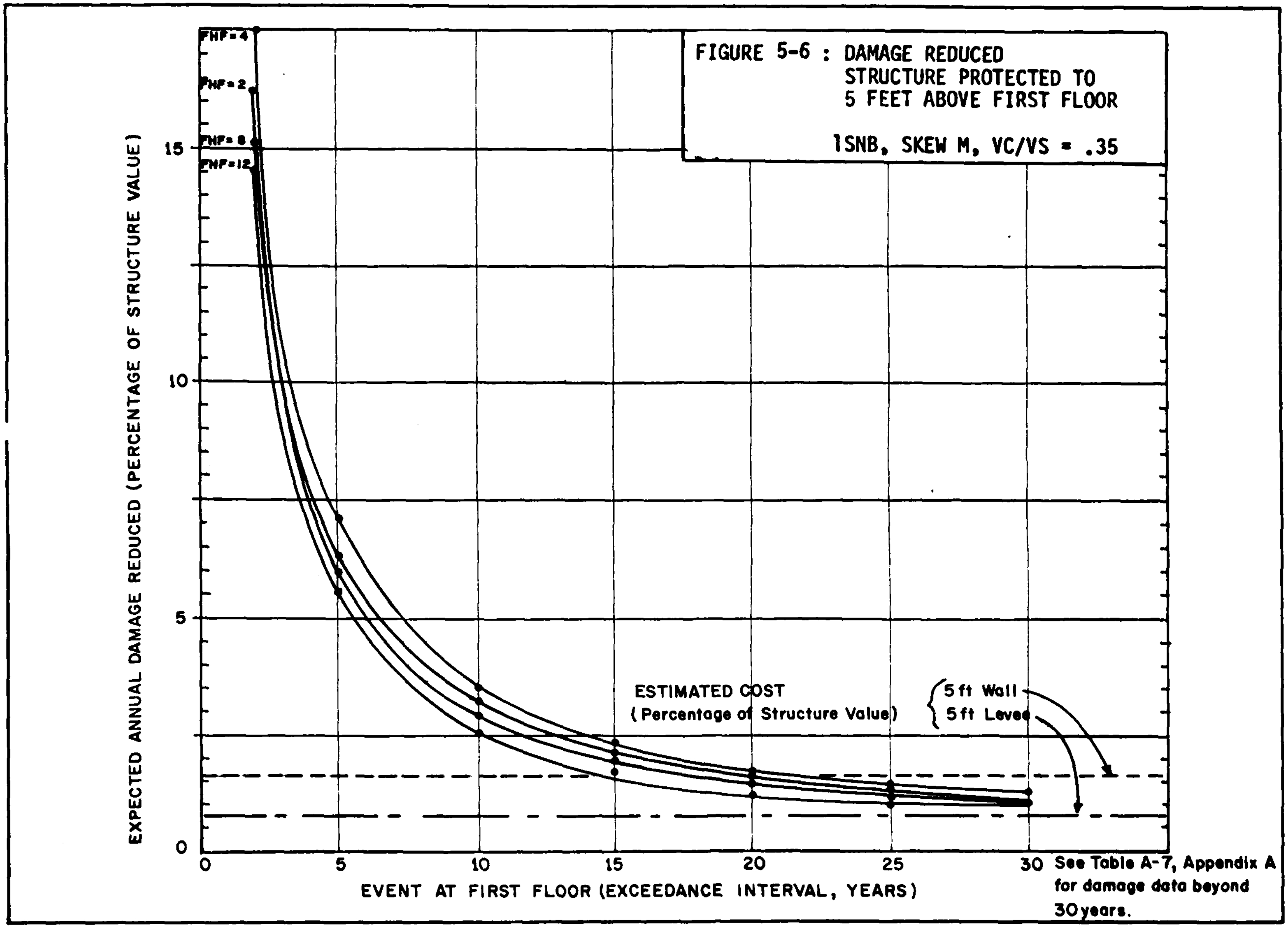


FIGURE 5-6 : DAMAGE REDUCED
STRUCTURE PROTECTED TO
5 FEET ABOVE FIRST FLOOR
1SNB, SKEW M, VC/VS = .35
FHF=4
FHF=2
FHF=8
FHF=12
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
0
5
10
15
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)
0
5
10
15
20
25
30
ESTIMATED COST
(Percentage of Structure Value)
5 ft Wall
5 ft Levee
See Table A-7, Appendix A for damage data beyond 30 years.

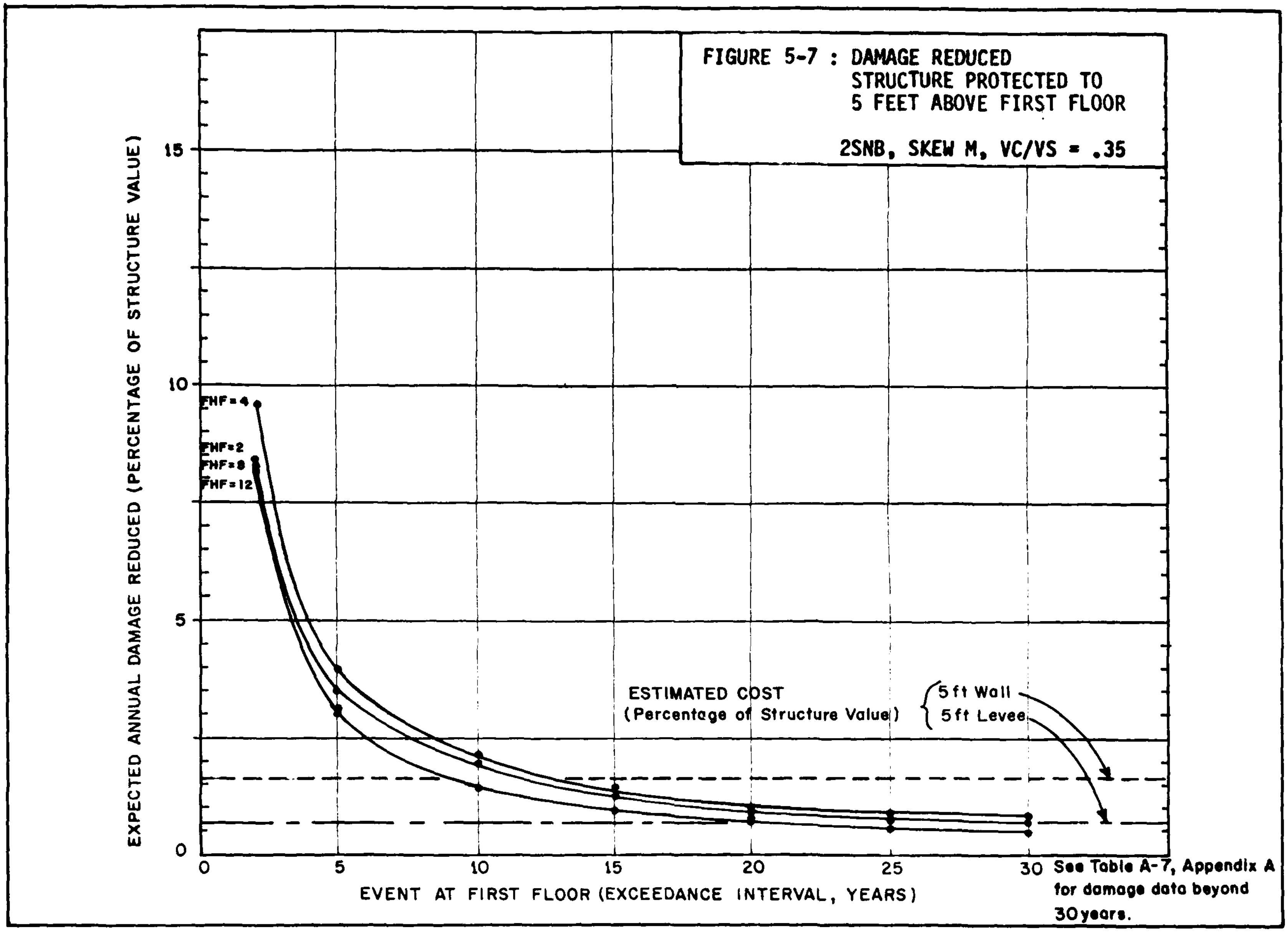


FIGURE 5-7 : DAMAGE REDUCED
STRUCTURE PROTECTED TO
5 FEET ABOVE FIRST FLOOR
2SNB, SKEW M, VC/VS = .35
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)
0
5
10
15
20
25
30
FHF=4
FHF=2
FHF=8
FHF=12
ESTIMATED COST
(Percentage of Structure Value)
5 ft Wall
5 ft Levee
See Table A-7, Appendix A for damage data beyond 30 years.

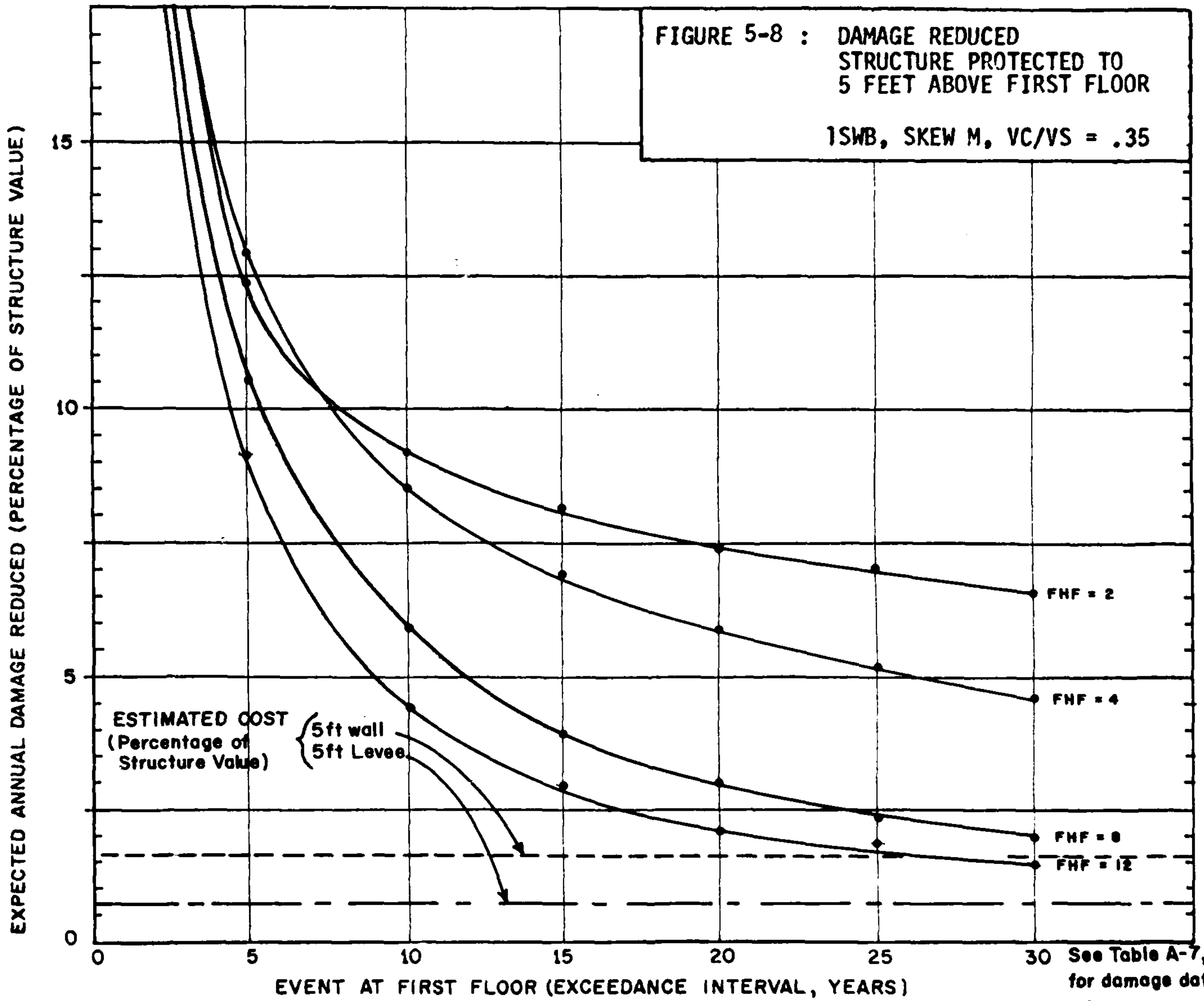


FIGURE 5-8 : DAMAGE REDUCED STRUCTURE PROTECTED TO 5 FEET ABOVE FIRST FLOOR

1SWB, SKEW M, VC/VS = .35

See Table A-7, Appendix A for damage data beyond 30 years.

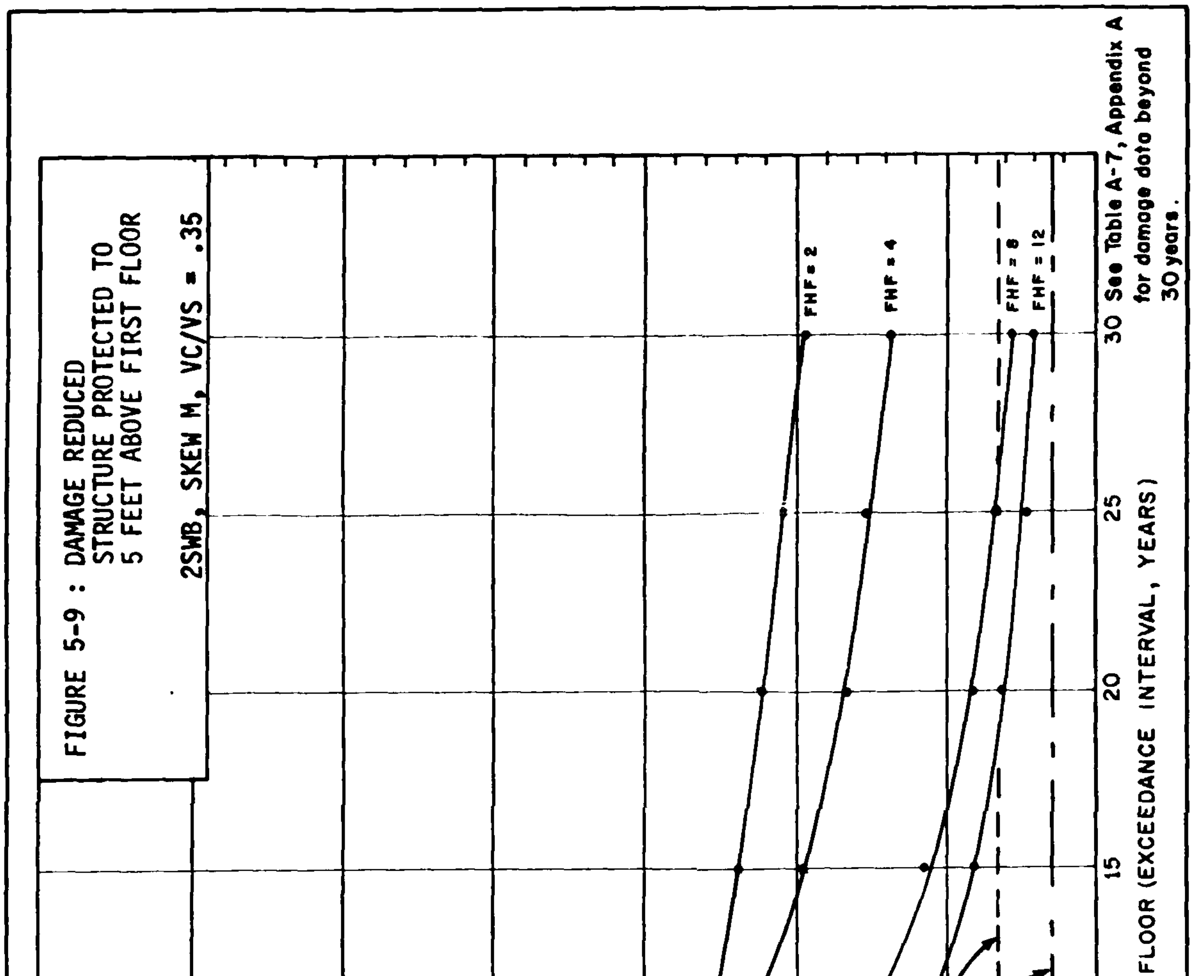


FIGURE 5-9 : DAMAGE REDUCED STRUCTURE PROTECTED TO 5 FEET ABOVE FIRST FLOOR

2SWB, SKEW M, VC/VS = .35

CHAPTER 6

REARRANGING OR PROTECTING DAMAGEABLE PROPERTY WITHIN AN EXISTING STRUCTURE

Description

Within an existing structure or group of structures damageable property can often be placed in a less damageable location or protected in-place. It is something every property owner can do to one degree or another depending upon the type and location of damageable property and upon the severity of the flood hazard. Examples of this action are described below and illustrated in Figure 6-1.

- Protecting furnaces, water heaters, air conditioners, washers, dryers, shop equipment and other similar property by raising them off the floor. This may be appropriate for shallow flooding conditions.
- Relocating damageable property (furnaces, water heaters, air conditioners, washers, dryers, etc.) to higher floors. Moving property from the basement to the first floor or second floor would be an example. This action usually requires altering ducts, plumbing, and electrical wiring and making space available at the new location.
- Relocating commercial and industrial finished products, merchandise and equipment to a higher floor or adjacent and higher building.
- Relocating finished products, materials, equipment and other moveable items located outside a structure to an adjacent, less flood-prone site.
- Protecting commercial/industrial equipment, especially motors, by placing them on a pedestal, table or platform.
- Anchoring all property which might be damaged by movement from flood waters. Combustible fuel stored in any form should be placed where it is above flood waters or secured in place.

In some flood hazard areas, such as behind levees, if inundation should occur during rare events it could be severe enough to completely fill a basement or even a first floor. While this is a rare condition it has occurred and the damage potential to the **structure** is great. Air uplift has the potential of moving a structure off its foundation and floating it to another location or causing structural failure of the roof. Studies have been done on ways to anchor a structure to its foundation and its roof to its superstructure (1). In the context of protecting structures at existing sites if this hazard does exist, appropriate anchorage and vents can be installed to reduce structural damage.

Physical Feasibility

The degree to which property can be rearranged and protected is site specific. It depends on the flood hazard, principally depth and frequency of flooding, upon the damageable property, its type, value, location and moveability, upon the availability, and adaptability of adjacent, less flood-prone locations, and upon whether the rearrangement can be maintained over a succession of flood-free years. Every structure has some property which can be either relocated or protected: the more there is, the more damage to be reduced. Shallow flooding allows the

use of protective type measures where appliances, utilities, equipment and goods can be raised in-place and protected. This saves finding new locations on other floors. Where the hazard is more severe and inundation is to greater depths, property will need to be relocated to prevent damage. This requires finding another location within the same structure or in an adjacent structure, if available. This may be easy or difficult depending upon specific site conditions.

Residual damage to both structure and contents will remain even when property is rearranged or protected. Also, there is the associated cost and inconvenience of clean-up. For these reasons protection of property seems to be given most serious consideration when other measures (including flood insurance) are either not physically or economically feasible, or the depth of flooding is relatively shallow. If flooding is regarded with concern by the property owner, partial protection although helpful, will probably not be satisfactory and a better means will be sought. When a better means cannot be found, rearrangement or protection will probably be used.

Costs

Costs to rearrange or protect damageable property depends upon the specific action taken. Many items in or around a residential structure can be protected by raising in place for less than $50 per item. Rearrangement is likely to be more expensive depending upon the alterations required, but could probably be done for less than $100 for many items. If new appliances, utilities, or equipment were being installed (perhaps to replace property damaged in a recent flood) the cost to install it at a less flood-prone location would probably be small. In commercial/industrial structures costs to move merchandise or equipment to another floor or raise it off the floor are difficult to estimate. In one structure the cost may be high, in another low.

Economic Feasibility

When damageable property is rearranged or protected within a structure, damage is reduced because the property is less susceptible to flooding. Usually this means it is higher, in which case it is flooded less frequently. Because this measure deals principally with individual property items, conventional depth-damage relationships are generally not applicable since they are usually constructed for the entire structure or its contents. Rather than the conventional approach (which would probably be used for expensive items) an assessment would probably be made which considers the cost to relocate or protect, the damage caused by flooding, the frequency of flooding, inconvenience, and the availability of alternative locations. In the case of such items as fuel tanks, safety is an additional consideration. No attempt was made in this study to quantify damage reduced, although it was generally felt that because of the wide range of opportunities, savings in damage would exceed costs and the measure would be economically feasible in many situations.

Advantages and Disadvantages

Table 6-1 below presents in summary form advantages and disadvantages of rearranging and protecting damageable property in existing structures.

TABLE 6-1

ADVANTAGES AND DISADVANTAGES OF REARRANGING AND PROTECTING DAMAGEABLE PROPERTY WITHIN AN EXISTING STRUCTURE

Advantages	Disadvantages
Most any residential, commercial or industrial property owner can do this to one degree or another.	Damage can be reduced only on those items which can be relocated or protected.
It can be done on a per item basis thus reducing the cost and allowing selective protection of high value contents.	A potential residual damage to the structure and contents not relocated or protected remains.
A structure can continue to be used at its existing site.	New patterns must be established for relocated property.

References

1. Carling, John G., William Kuaternik and Roger E. Carrier, "Handbook of Flood-Resistant Construction Specifications", Pennsylvania Department of Community Affairs, December 1976.

CHAPTER 7

REMOVAL OF EXISTING STRUCTURES AND/OR CONTENTS FROM A FLOOD HAZARD AREA

Description

Chapter 6 discussed relocating and protecting damageable property within an existing structure. This Chapter discusses two options for removing property to a location outside the flood hazard area. One option is to remove both structure and contents to a flood free site. This involves:

- Locating and purchasing land at a new site.
- Preparing the new site; services, driveway, sidewalk, new foundation.
- Raising structure off its existing foundation, transporting it to the new site and placing it on the new foundation.
- Moving contents from existing to new location.
- Removing, disposing, and backfilling the foundation at the existing site.
- Providing temporary lodging during relocation.

A second option is to remove only the contents to a structure located at a flood-free site and demolish or reuse the structure at the existing site. If the structure is reused it should be for a use which has contents which are not readily damageable. Preserving a structure for historic purposes is an example. In both cases — demolition or reuse — the measure includes,

- Locating an existing structure, or building a new structure, at a flood-free site.
- Moving contents from an existing to a new location.
- Either demolishing, and where possible salvaging, the existing structure, or reusing it for a less damage susceptible use.

Figure 7-1 illustrates some of these options graphically. There are also other possibilities such as removing part of the contents, or relocating one of a group of structures, or modifying an existing structure to accommodate a new use. In each case the purpose is to remove damageable property from the hazard area, yet take advantage of opportunities for using the existing property in ways which are compatible with the hazard. Reference 1 describes an application of these measures.

Physical Feasibility

While the experience and equipment exists for moving many different types of structures, either as a whole or in segments, there is a practical limit on the size and type structure which it is economically feasible to move to reduce flood losses. Even the most readily relocatable structures are costly to remove. For this reason the discussion in this Chapter will center on identifying the most favorable removal situations.

One or two story residential and light commercial structures of wood frame on raised foundations or basements are usually easy to move because of the structure weight and access to the first floor joists. Structures of brick, concrete or masonry can also be moved, however, additional precautions must be taken to prevent excessive cracking. Structures with slab-on-

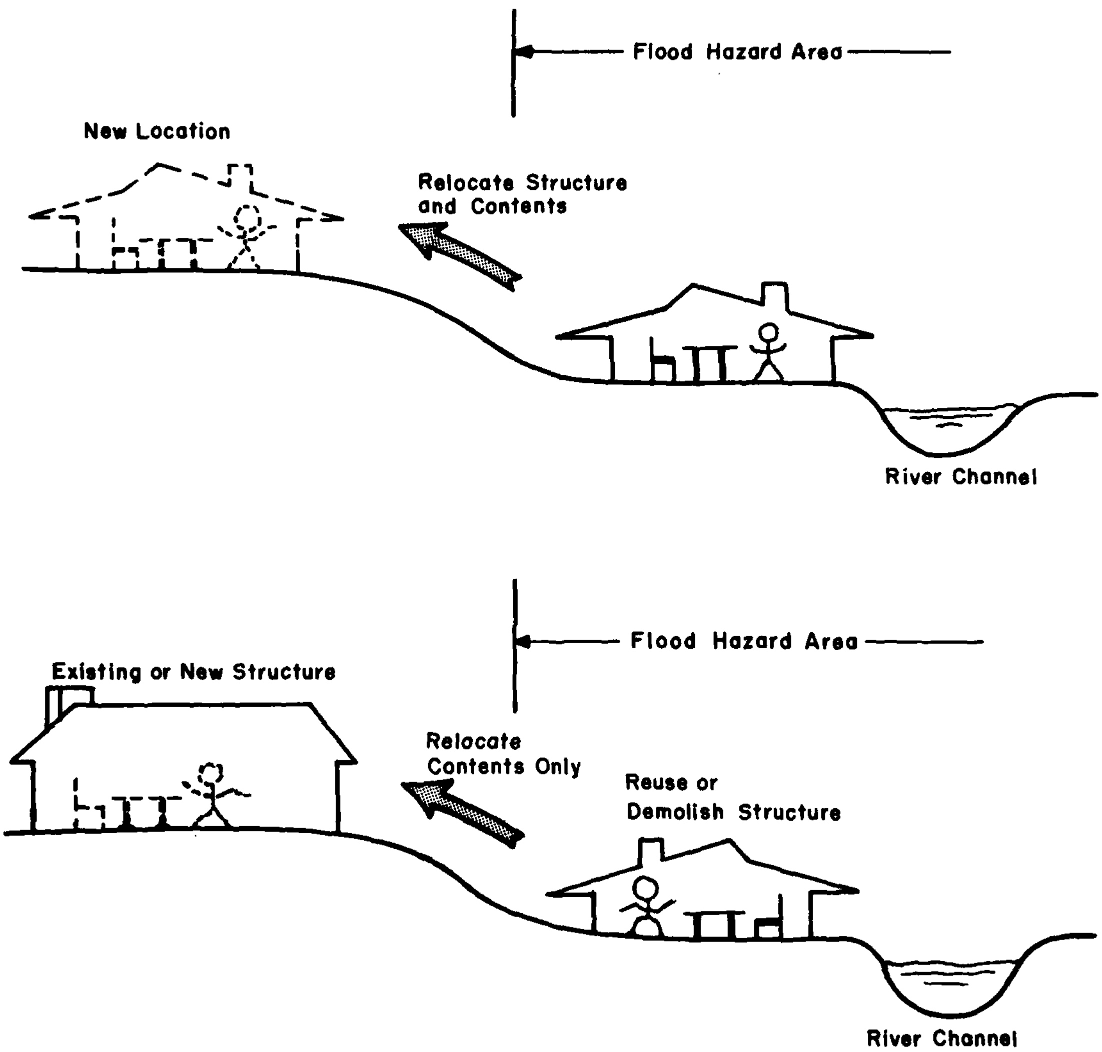


Figure 7-1. Removal of Existing Structure and/or Contents

grade foundations pose special problems because of the difficulty of getting lift supports under the structure, the danger of cracking the slab, and the problems of placing it on a new foundation. Therefore, it is generally considered to be infeasible. Row houses and apartments pose similar problems and are not usually feasible to move.

Most commercial and industrial buildings are not feasible to move because of their size and type construction. Often they are large and heavy with slab-on-grade foundation. Rather than relocate the structure (assuming it cannot be flood proofed), it is usually more feasible to remove the contents and find a new use for the structure. Similar action is sometimes taken when the damage potential to contents is high, as with high value merchandise or machinery. In such cases, if the contents cannot be protected in some other way they are often relocated out of the flood hazard area.

The decision to remove structures and/or contents to a flood-free site, assuming it is physically feasible, is usually influenced by a number of other considerations. Relocation is less desirable where an activity is dependent upon unique resources provided at the site, or where there is a lack of such resources at available new sites. This could be convenience to shopping or work for residences, or dependence on business activity for commercial structures. Industrial plants may be dependent upon water or land resources, or a rail or highway network. In each of these examples relocation may be limited by the availability of comparable flood-free sites.

Costs

Costs to remove an existing structure and/or contents to a flood-free site, from the viewpoint of a Federal agency, are of two types: Costs to acquire the existing structure and property, and costs to provide relocation assistance. Acquisition costs depend upon the conditions agreed upon for transfer of title. If a structure is to be relocated these costs include,

- New site purchase and preparation.
- Moving structure to new site.

If only contents are to be removed costs include,

- Acquisition of existing structure and site.
- Demolition of existing structure if it is not to be reused.
- Modification of existing structure as required if it is to be reused.

Relocation assistance costs apply to those items covered under Public Law 91-646, "Uniform Relocation Assistance and Land Acquisition Policies Act of 1970". These include,

- Moving and related expenses.
- Replacement housing for homeowner.
- Replacement housing for tenants.
- Costs to convey property to the government.

Moving and related expenses include: reasonable costs for moving up to 50 miles from the acquired property; reimbursement for business or farm items not moved; remibursement of reasonable expenses incurred in searching for a replacement business or farm; loss of patronage because of move to a new location (this item is in lieu of the above three).

Replacement housing for homeowners includes: an amount, which when added to the acquisition cost, equals the reasonable cost of a comparable replacement dwelling which is

decent, safe, and sanitary, and reasonably accessible to public services and places of employment; an amount to cover the increased interest costs to finance a replacement dwelling; reasonable expenses for title, recording fees, and other closing costs incurred for the purchase of a replacement dwelling.

For persons other than homeowners (tenants) replacement housing includes: an amount to enable a tenant to lease, rent, or purchase a decent, safe, sanitary dwelling which is reasonably accessible to public facilities and places of employment.

Costs to convey property to the government are also reimburseable under the Act. These costs include: recording fees, transfer taxes and similar expenses, mortgage prepayment penalty costs, real property taxes already paid.

Engineer's cost estimates were made for the two removal options being considered and these are summarized in Tables 7-1 and 7-2.

TABLE 7-1

ESTIMATED COSTS TO REMOVE STRUCTURE AND CONTENTS TO A FLOOD-FREE SITE[1]

Item		Estimated Cost
New Site Purchase and Preparation		$11,950.
Moving Structure to New Site[2]		3,200.
Moving and Related Expenses		600.
Replacement Housing for Homeowner		1,000.
Costs to Convey Property to Government		400.
Total First Cost	=	$17,160.
Annual Cost[3]	=	$ 1,375.
Annual Cost as a Percentage of Structure Value	=	4.6

[1] Estimated for a $30,000, 1600 square foot structure. Land value of a new site was assumed to be $5,000.

[2] Costs include 25 percent for contractor's bonds, overhead, profit, and engineering.

[3] Amortized at 7 percent for 30 years.

TABLE 7-2

ESTIMATED COSTS TO REMOVE CONTENTS TO A FLOOD-FREE SITE AND DEMOLISH EXISTING STRUCTURE[1]

Item		Estimated Cost
Acquisition of Existing Structure and Site[2]		$25,500.
Demolition of Existing Structure[3]		5,100.
Moving and Related Expenses		600.
Replacement Housing for Homeowner[4]		1,000.
Costs to Convey Property to Government		400.
Total First Cost	=	$32,600.
Annual Cost[5]	=	$ 2,612.
Annual Cost as Percentage of Structure Value	=	8.7

[1] Costs were estimated assuming a 1600 square foot structure in a flood-free location was valued at $30,000 and land at $5,000.

[2] The value of the structure in the flood hazard area was assumed to be $5,000 below market value of structures at flood-free sites and land value was assumed $500.

[3] Costs include 25 percent for contractor's bonds, overhead, profit and engineering.

[4] Replacement cost is sometimes interpreted as being the additional cost to provide a comparable structure at a flood-free site. Under this interpretation this cost could be over $9,500 since an additional $5,000 would be needed for a comparable structure and $4,500 for flood-free land. This cost item is limited to $15,000 by the Act.

[5] Amortized at 7 percent for 30 years.

These data show an annual cost of 4.6 percent of structure value, where both structure and contents are removed to a flood-free site, and 8.7 percent where only contents are removed and the structure is demolished. These values represent the approximate lower and upper bound of a range of costs which will vary depending upon the assumptions made regarding disposition of existing property and availability of a new site. Removal and reuse of an existing structure at a flood-free site is the most economical option because existing resources are being reused. The least economical option is to forego both structure and site and simply remove the contents.

Economic Feasibility

With a structure and contents located at a flood hazard site flood damage occurs; with both structure and contents removed to a flood-free site this damage is eliminated. The damage reduced by removal is the amount of damage which would have occurred had the structure not been removed. Figures 7-2 through 7-5 show this damage for four type structures at different locations in the flood plain and different flood hazard factors. Details of this analysis are

discussed in Appendix A. The damage reduced shown is the maximum possible for these conditions since removal eliminates all damage to structure and contents.

In Federal planning a distinction is made between damage reduced by relocation, and benefits. Benefits include cost savings to non-users, for example, Federal Flood Insurance subsidies, emergency evacuation, other public savings. They do not generally include damage reduced because it is reflected in the reduced value of flood plain property.

Annual costs as a percentage of structure value developed in Tables 7-1 and 7-2 are also shown on Figures 7-2 through 7-5. A percentage of 4.6 corresponds to removing both structure and contents to a flood free site and 8.7 percent corresponds to removing only contents and demolishing the existing structure. A comparison of cost and damage reduced shows that removing both structure and contents is economically feasible for,

- A one or two story, no basement, structure below approximately the 5 year flood plain and flood hazard factor of 2.0 feet, and below about the 10 year flood plain and a flood hazard factor of 12.0 feet.
- A one story, with basement, structure below the 15 year flood plain with flood hazard factor of 8.0 feet or more; below the 30 year event with a flood hazard factor equal to 4.0 feet; and below the 100 year flood plain with a flood hazard factor of 2.0 feet. The flood hazard factor is particularly important when assessing damage to this type structure. (For an explanation of why expected annual damage decreases with increasing flood hazard see Appendix A.)
- A two story, with basement, structure below the 10 year flood plain for a flood hazard factor of 8.0 feet or greater, and below the 30 year for a flood hazard factor of 2.0 feet.

To remove contents only and demolish the existing structure (the more costly option) these data show that structures without basements must be located approximately below the 5 year flood plain, and structures with basements must be located approximately below the 10 year flood plain. There is some variability depending upon the flood hazard factor, but less than when structure and contents are removed.

Advantages and Disadvantages

Tables 7-3 and 7-4 summarize advantages and disadvantages of the two removal options being discussed in this Chapter.

TABLE 7-3

ADVANTAGES AND DISADVANTAGES OF REMOVING EXISTING CONTENTS FROM A FLOOD HAZARD AREA AND DEMOLISHING OR REUSING THE STRUCTURE

Advantages	Disadvantages
Flood damage to the existing contents is eliminated. If the structure is demolished structural damage is eliminated.	Damage to the structure and site remain if the structure is reused. Costs to remove contents and demolish the structure are high relative to other measures.

TABLE 7-4

ADVANTAGES AND DISADVANTAGES OF REMOVING EXISTING STRUCTURE AND CONTENTS FROM A FLOOD HAZARD AREA

Advantages	Disadvantages
Flood damage is eliminated, there is no residual damage.	Compared with other measures for existing structures removal is costly.
Removal allows land use adjustments which may be beneficial to the community.	Advantages associated with being at the flood plain site are lost.
Improved hydraulic performance for passing flood flows.	The vacated site remains requiring continued maintenance with associated costs.
Maintenance of flood plain land may be reduced.	

References

1. U.S. Army Engineers, "Feasibility Report, Burnett, Crystal, and Scotts Bay and Vicinity, Baytown, Texas", Galveston, Texas, January 1975.

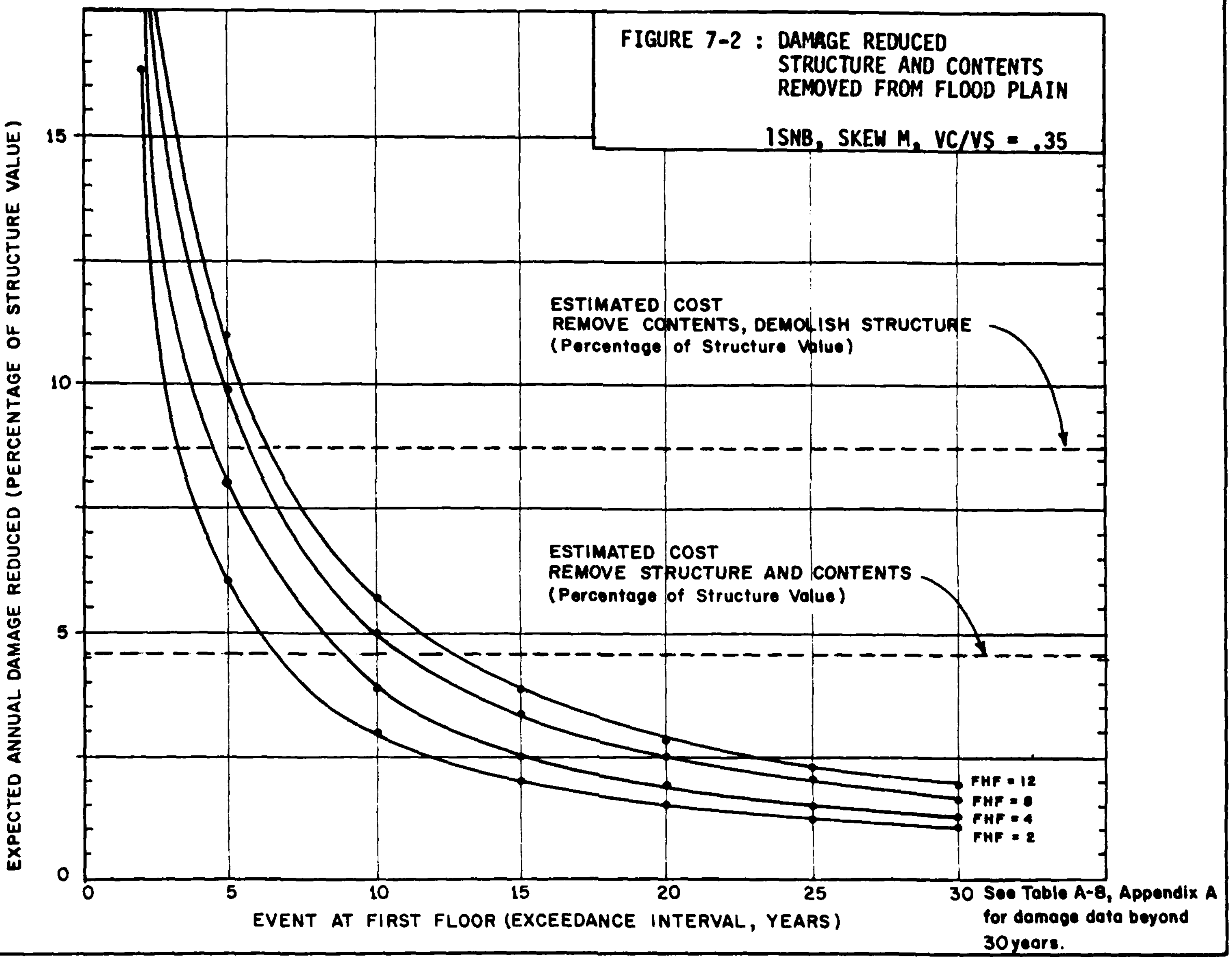


FIGURE 7-2 : DAMAGE REDUCED STRUCTURE AND CONTENTS REMOVED FROM FLOOD PLAIN

1SNB, SKEW M, VC/VS = .35

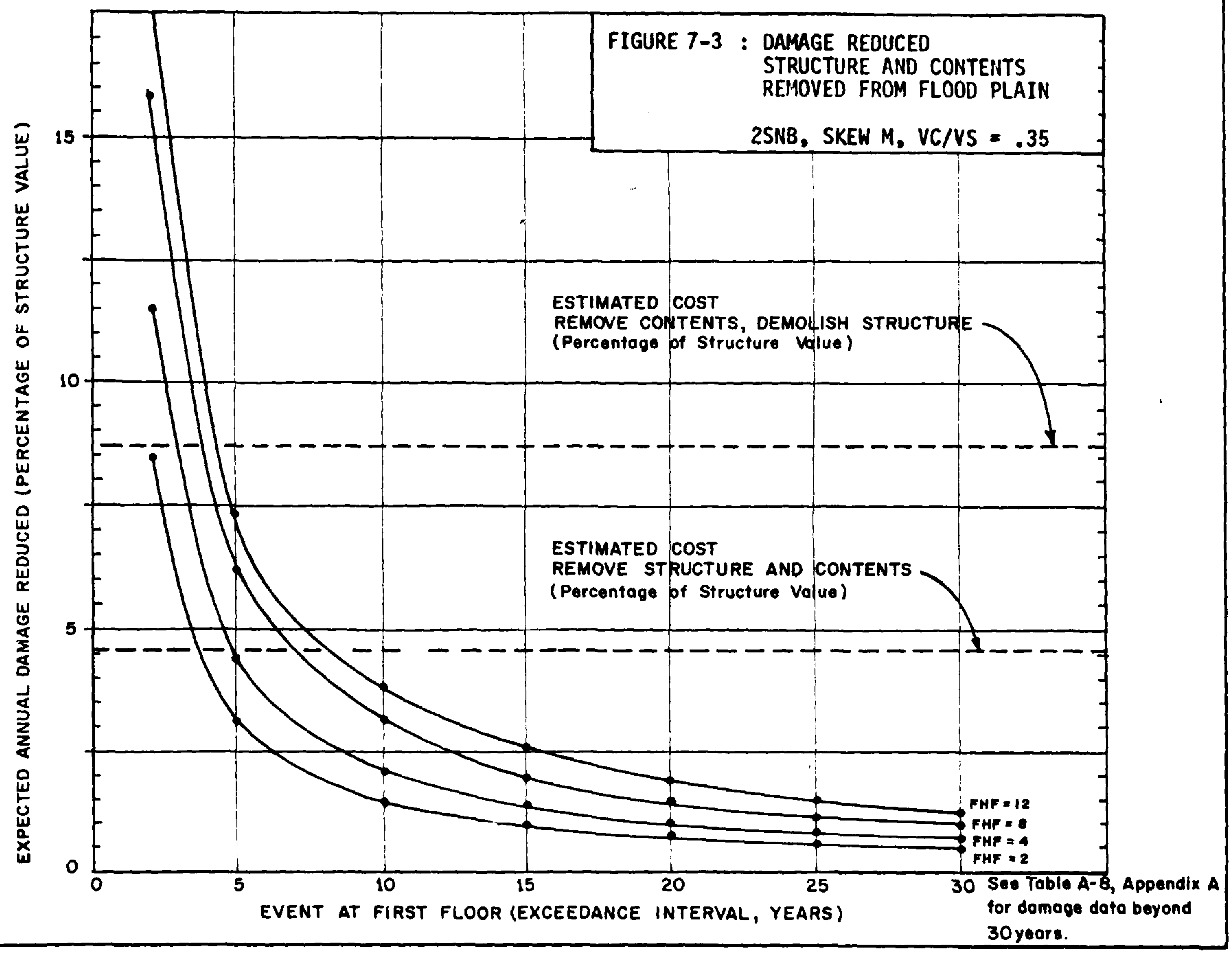


FIGURE 7-3 : DAMAGE REDUCED
STRUCTURE AND CONTENTS
REMOVED FROM FLOOD PLAIN

2SNB, SKEW M, VC/VS = .35

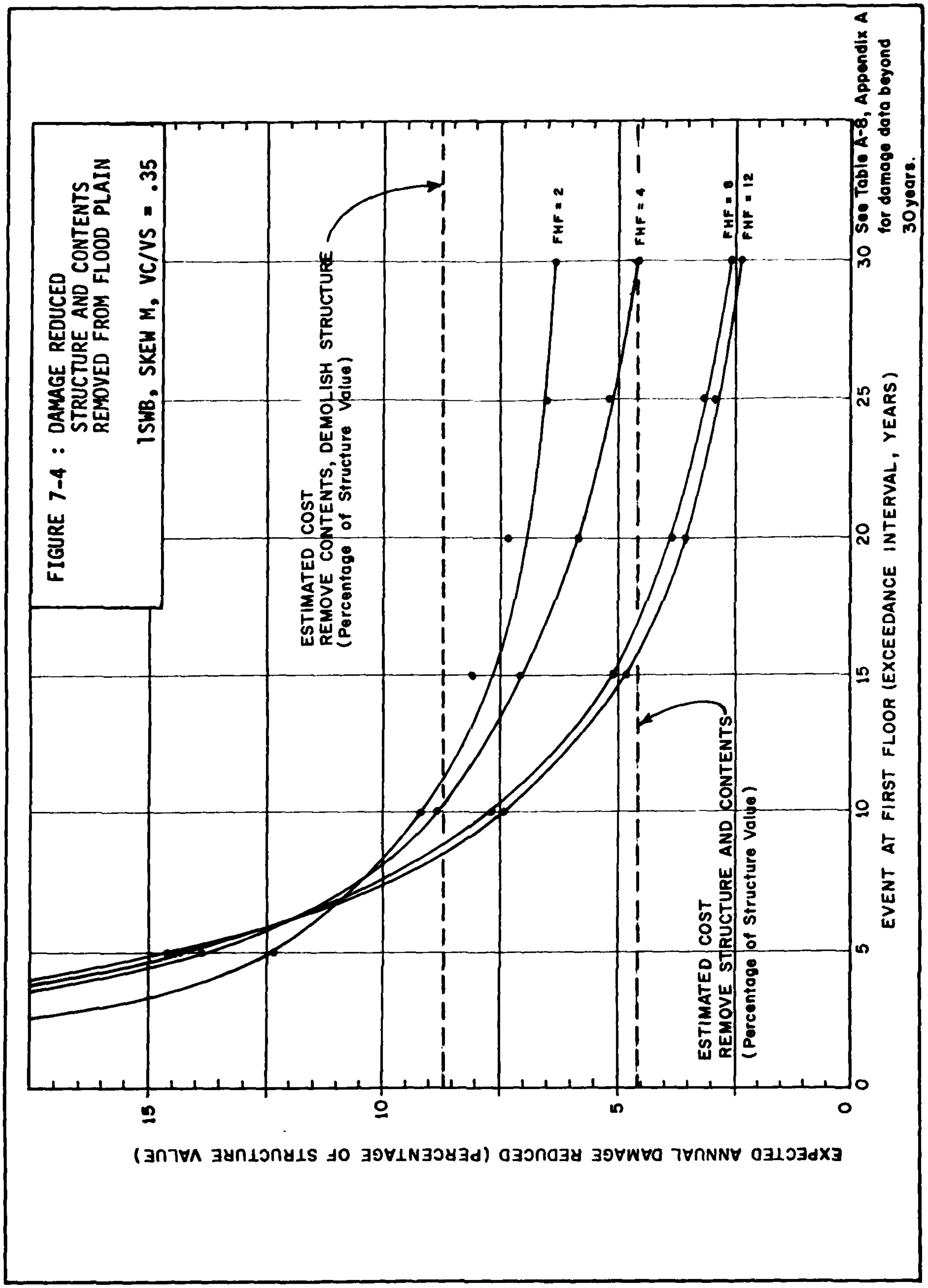


FIGURE 7-4 : DAMAGE REDUCED
STRUCTURE AND CONTENTS
REMOVED FROM FLOOD PLAIN
1SWB, SKEW M, VC/VS = .35
ESTIMATED COST
REMOVE CONTENTS, DEMOLISH STRUCTURE
(Percentage of Structure Value)
ESTIMATED COST
REMOVE STRUCTURE AND CONTENTS
(Percentage of Structure Value)
FHF = 2
FHF = 4
FHF = 8
FHF = 12
See Table A-8, Appendix A for damage data beyond 30years.
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
0
5
10
15
20
25
30
0
5
10
15

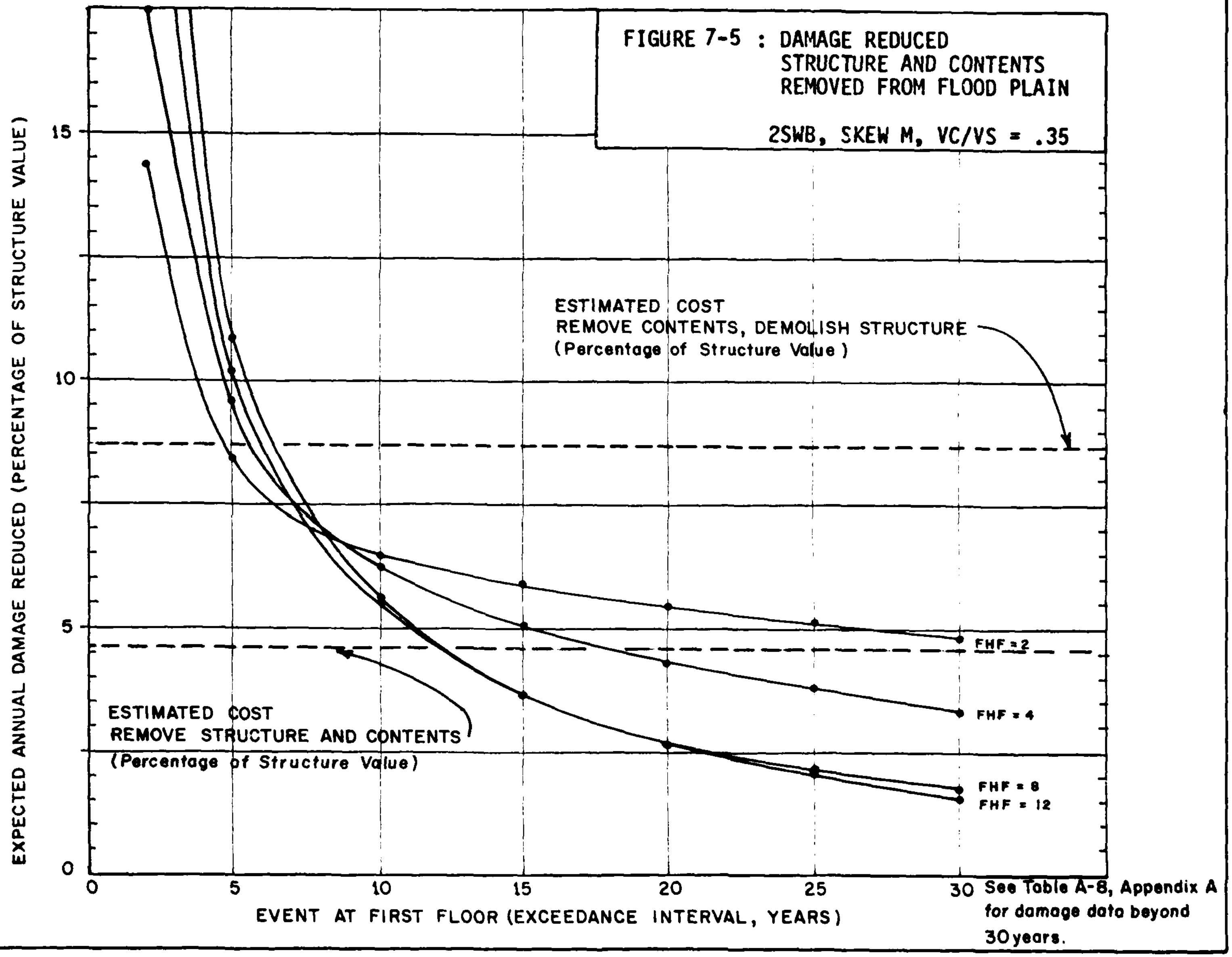


FIGURE 7-5 : DAMAGE REDUCED STRUCTURE AND CONTENTS REMOVED FROM FLOOD PLAIN

2SWB, SKEW M, VC/VS = .35

CHAPTER 8

FLOOD FORECAST, WARNING, AND EVACUATION

Description

Flood forecast, warning, and evacuation is a strategy to reduce flood losses by charting out a plan of action to respond to a flood threat. The strategy includes,

- A system for early recognition and evaluation of potential floods.
- Procedures for issuance and dissemination of a flood warning.
- Arrangements for temporary evacuation of people and property.
- Provisions for installation of temporary protective measures.
- A means to maintain vital services.
- A plan for post-flood reoccupation and economic recovery of the flooded area.

Figure 8-1 illustrates the basic interaction between components of this strategy. Each covers a broad spectrum of actions and reactions varying from responding to a visual flood threat to sophisticated flood forecast, warning, and evacuation systems. The more sophisticated systems require coordinated assistance from local, state and federal agencies.

Systems for early recognition and evaluation of potential floods are generally of two types: Those for flooding of major stream systems and those related to flash floods. The National Weather Service (NWS) has 13 River Forecasting Centers and 82 River District offices located throughout the United States. Generally their forecasts predict stages on major river systems. Flash flood systems are of many different types(3,4). These include,

- Self-contained community or county forecasting systems.
- Automatic flash flood alarm systems.
- NWS forecasting charts.
- Weather warning broadcasts.
- Manual observations.

Flood warning is the critical link between forecast and response. An effective warning process will communicate the current and projected flood threat, reach all persons affected, account for the activities of the community at the time of the threat (day, night, weekday, weekend), and motivate persons to action. The decision to warn must be made by responsible agencies and officials in a competent manner to maintain credibility of future warnings.

An effective warning needs to be followed by an effective response. This means effective and orderly evacuation of people and property. Actions which can facilitate this include

- Establishment of rescue, medical and fire squads.
- Identification of rescue and emergency equipment which can be utilized during a flood.
- Identification of priorities for evacuation.
- Surveillance of evacuation to insure safety and protect property.

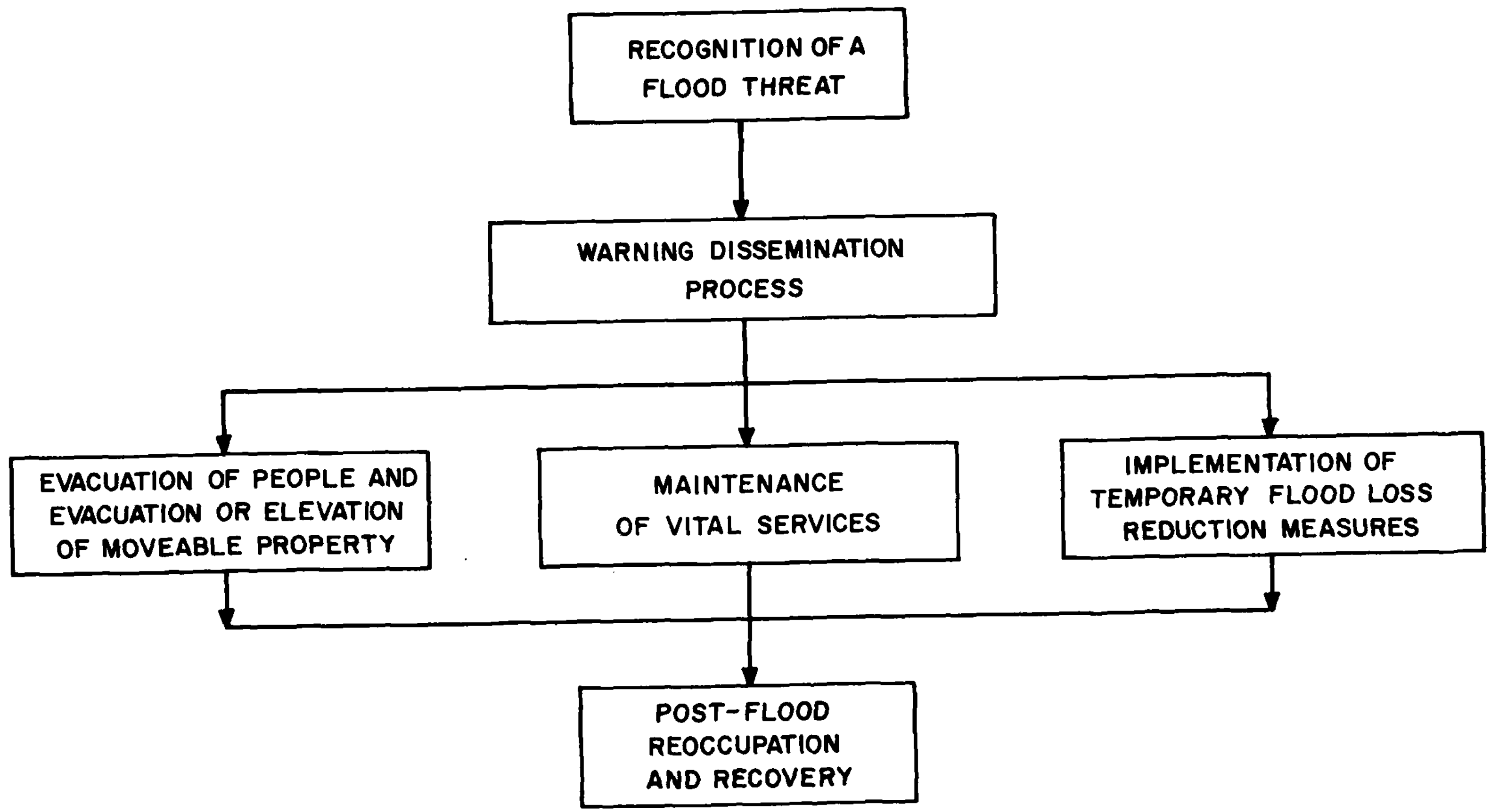


Figure 8-1. Flood Forecast, Warning, and Evacuation Strategy

In addition to evacuation, property can be protected by various protection measures. These include: temporary flood proofing of structures, use of pumps, and flood fighting. Flood fighting includes such actions as raising the level of existing protection, closing highways, streets and railroads, prevention of backwater in sewers, and protection against erosion. All of these actions contribute to the overall goal of reducing flood loss.

In addition, a forecast, warning, and evacuation strategy will include maintenance and management of vital services before, during, and after the flood and post-flood reoccupation and recovery. Vital services include telephone, energy (gas and electric), sewage, water, traffic control, hospitals, as well as, police and fire services. Post-flood reoccupation and recovery includes,

- Reestablishment of conditions which will not endanger public health: disease and insect control, safe drinking water, safe sewage disposal, medical supplies.
- Return of other vital services.
- Removal of sediment, debris, flood fighting equipment and materials.
- Repair of damaged structures.
- Establishment of disaster assistance centers for financial and other assistance.

A detailed discussion of each of the above components is presented in Appendix C. An overview is described in Reference 1.

Physical Feasibility

The factors which determine the physical feasibility of forecast, warning and evacuation measures are somewhat different from those which determine the physical feasibility of many other nonstructural measures. The feasibility of most other measures is directly related to the type structure and depth of flooding. Forecast, warning, and evacuation feasibility is more dependent upon hydrologic, social, and institutional factors. The selection and feasibility of forecasting capability depends upon the size of the drainage area; whether the river is a main stem or tributary, travel time; and other hydrologic factors which influence the ability to make reliable forecasts. Small watersheds generally have short response times making it especially difficult for warning to be helpful. The feasibility of warning systems also depends upon such social factors as the size and distribution of people in a community, the type of community (business district or suburb), and the type of communications network available or capable of being installed. One system may be appropriate for one community, but not for another. The feasibility of implementing temporary protective measures, the means to maintain vital services, and a plan for post-flood recovery are dependent also on community factors and institutional arrangements. An infrastructure of community and institutional arrangements is necessary to effectively use hydrologic information. If this infrastructure cannot be created, or only created to a limited degree, this influences the feasibility of different warning and evacuation measures.

Specific comments on the physical feasibility for each forecast, warning and evacuation component are presented in Appendix C. In general, some level of preparedness planning is feasible for most every community, but the extent and type will depend upon local conditions.

Costs

Costs vary widely with the component of the preparedness strategy being implemented. Appendix C contains cost information for some components. Where a reasonable estimate could not be made only the items entering into estimating costs were presented.

Economic Feasibility

Damage reduced through forecast, warning, and evacuation is particularly difficult to measure because of the many variables, both in the types of actions which might be taken and the affects of these actions. In one study on economic feasibility it was found that damage reduced exceeded costs by three to seven times, however, it is dangerous to generalize from these data as each flood plain or river basin is unique (2). While the costs of preparedness occur each year the flood events being prepared for are generally less frequent. When they become quite infrequent it may be justified (economically, as well as practically) to invest in some other means of protection even though the annual costs are low. The difficulty, of course, is that floods are more or less random events and as such are not usually spaced evenly over time.

Advantages and Disadvantages

The principal advantages and disadvantages of forecast, warning, and evacuation as a means of reducing flood damage are summarized in Table 8-1.

TABLE 8-1

ADVANTAGES AND DISADVANTAGES OF FLOOD FORECAST, WARNING, AND EVACUATION MEASURES

Advantages	Disadvantages
Preparedness planning is almost always economically feasible and desirable. Something can usually be done even in areas where other flood loss reduction measures are implemented.	The effectiveness of the warning system and response of the community cannot be accurately predetermined, consequently neither can potential flood damage reduction.
A significant saving of lives may result in flash flood or water related structural failure situations.	Requires a continuous awareness and information program, maintenance of equipment, etc.
Accurate forecasts and warnings may permit sufficient time to implement temporary protective measures which can significantly reduce flood damage.	Effectiveness of preparedness plans tend to diminish with increasing time between floods.

References

1. Owen, H. James, "Guide for Flood and Flash Flood Preparedness Planning", National Oceanic and Atmospheric Administration, National Weather Service, April 1976.

2. Day, Harold J., "Flood Warning Benefit Evaluation - Susquehanna River Basin (Urban Residences)", Environmental Science Services Administration, Weather Bureau, U.S. Department of Commerce, ESSA Technical Memorandum WBTM HYDRO 10, March 1970.

3. Susquehanna River Basin Commission, "Planning Guide, Self-Help Flood Forecast & Warning System, Swatara Creek Watershed Penna.", Mechanicsburg, PA., November 1976

4. Susquehanna River Basin Commission, "Neighborhood Flash Flood Warning Program Manual", Mechanicsburg, PA, October 14, 1976.

CHAPTER 9

ELEVATING NEW STRUCTURES

Description

New residential structures or substantial additions to existing structures to be built on flood hazard sites are required, under the National Flood Insurance Program, to have their lowest floor elevated to or above the base flood level. In coastal zones it is the lowest portion of the structural members of the lowest floor which must be elevated to this elevation. Nonresidential structures have the option of making a structure watertight or elevating. The idea of elevating a structure is not new, however. Numerous residential and commercial structures built in flood hazard areas have been elevated for years (1). The means used varies depending principally upon aesthetics, the type and use of structure, availability of materials, and upon the nature of the flood hazard. Commonly used methods include: earth fill, concrete walls, and wood, steel, concrete or masonry posts, piles or piers. Figure 9-1 shows several structures elevated in this manner and Reference 1 describes the methods in detail.

Physical Feasibility

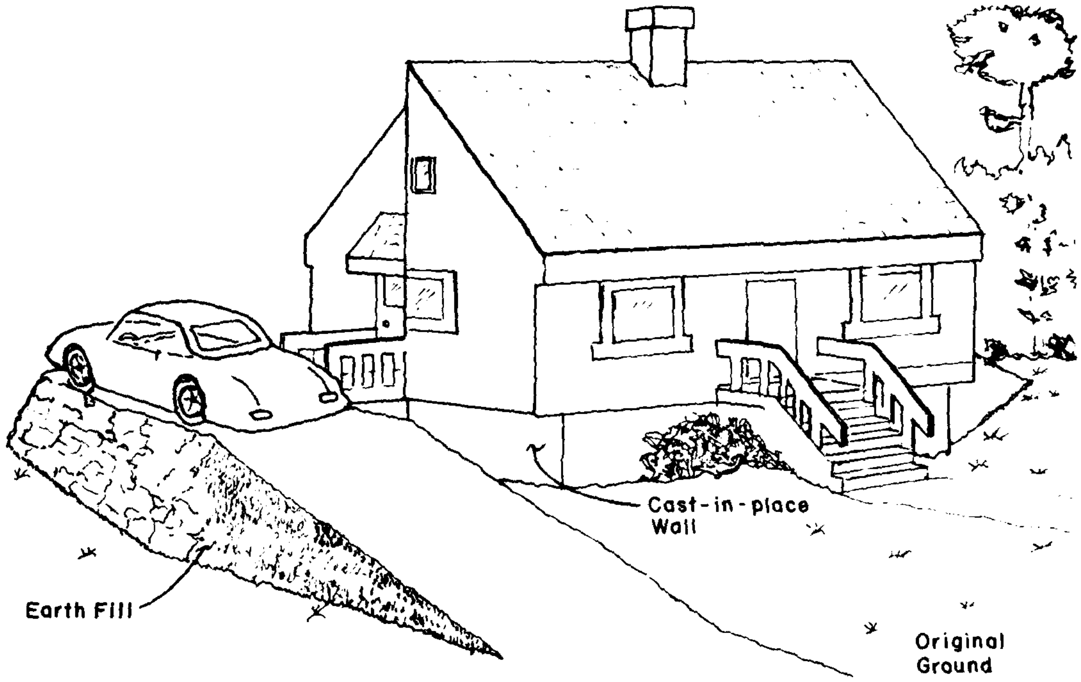
Earth fill is commonly used in residential subdivisions, shopping centers, industrial parks, as well as for individual structures. It is especially suited for use over large areas because not only can the structures be elevated, but utilities, roads and storage areas are elevated as well. It has the added advantage of being placed and contoured in a manner which makes it harmonize with natural terrain. It is applicable to individual structures although the landscaping has to be unique for each structure.

The principal factors which govern the use and height of earth fill are:

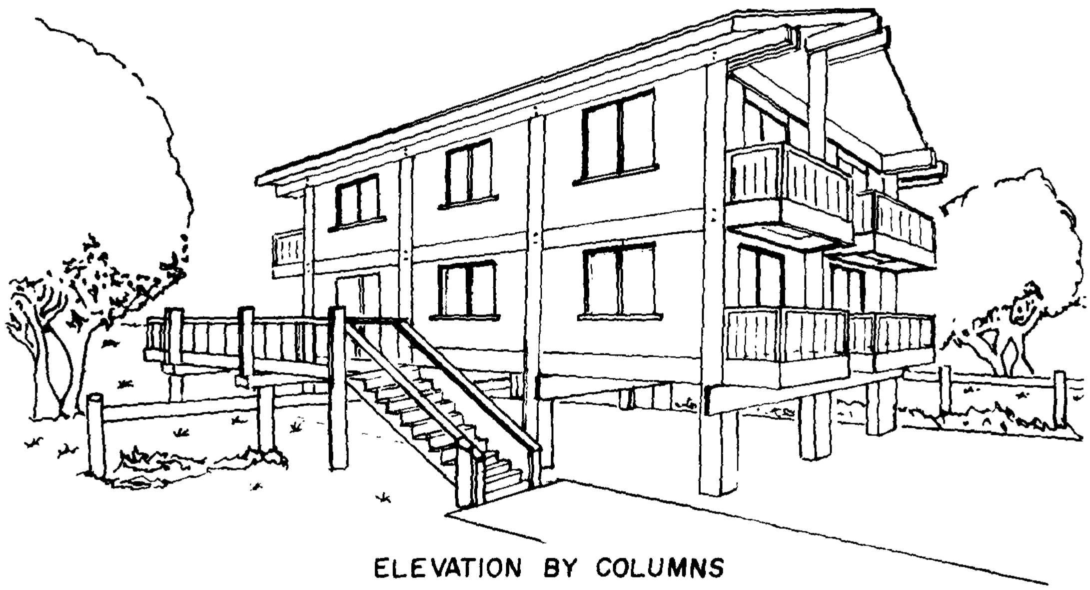
- Availability - adequate amounts and quality of fill material must be available locally.
- Settlement - foundation material upon which fill is placed and the fill itself must be capable of supporting both fill and structure within acceptable limits of settlement.
- Erosion - slopes exposed to erosive flow must be protected.
- Compensatory Storage and Flow Cross-Section - when extensive areas of the flood plain fringe are filled it may be necessary to provide compensatory storage or flow cross section to prevent increased peak flows downstream and higher flood stages upstream. Both must be maintained and kept free from sediment encroachment.
- Aesthetics - the height and location of earthfill should be compatible with the natural landscape. Often this is a limiting factor regarding height of fill. Placement (location and height) can also influence the market value of adjacent land.

Columns, piers, posts and piles are structural members commonly used as foundation supports for residential, commercial and industrial buildings. The selection of the appropriate type is influenced by the following factors:

- Settlement - foundation material upon which the support posts and the support itself must be capable of carrying the load of the structure and any other design loads.
- Scour - foundations must be capable of being designed to be protected against scour.



ELEVATION BY CAST-IN-PLACE FOUNDATION WALL



ELEVATION BY COLUMNS

Figure 9-1. Elevating New Structures
(Adapted from "Elevated Residential Structures," Federal Insurance Administration)

- Debris - where debris accompanies flood flows support members must be protected and designed to withstand associated impact forces.
- Aesthetics - architectural considerations frequently determine the type, height and arrangement of support members.

Earth fill and support members are applicable to a wide range of structures and flood hazard conditions. They may be used to elevate structures to most any height although local site conditions and architectural considerations usually impose practical limits. They may be used separately or together depending upon the need. While they both achieve the same purpose, that of elevating a structure to a less flood susceptible level, earth fill can also be used to elevate other damageable property — utilities, roads, bridges, storage areas — at the same time that structures are elevated. It has the additional advantage of reducing the susceptibility to scour and debris by keeping flood waters away from the structure.

Costs

The cost of elevating a new structure is measured as the difference between constructing a structure on a low foundation and the cost of constructing it elevated. If the same structure is to be built, but in an elevated position, the principal cost items are the fill and/or support members, access ramps and stairways, and additional duct work, wiring and plumbing. Frequently, however, the fact that the structure will be located in a flood hazard area results in the selection of a structure which is architecturally and functionally compatible with the hazard and not just a flood-free-site structure elevated. In this situation the cost of flood protection should be estimated using the structure types likely to be used with and without the hazard. Cost is also a function of height. Elevating to greater heights will normally increase labor and material costs.

Cost estimates using nationwide data show increased cost of elevating structures range from $1.10 to $2.32 per square foot of structure depending upon the type of foundation (Reference 1, Table 4-1). Slab-on-grade to concrete pier yielded the maximum increased cost and crawl space to wood pile the least. The height raised ranged from 6'0" to 7'2" depending upon the type of foundation. For purposes of this study, minimum costs for elevating a 1,600 square foot, $30,000 structure three feet and five feet were estimated to be $1.10 and $1.50 respectively. Table 9-1 shows the approximate annual cost as a percentage of structure value.

TABLE 9-1

ESTIMATED COST TO ELEVATE A NEW STRUCTURE ON FILL OR COLUMNS

Item	Estimated Cost to Elevate 3 Feet[1]	Estimated Cost to Elevate 5 Feet[3]
Increased Cost to Elevate	$1760.	$2400.
Total First Cost	$1760.	$2400.
Annual Cost[2]	$ 142.	$ 193.
Annual Cost as Percentage of Structure Value	0.5	.6

[1] Based on an estimate of $1.10 per square foot for a 1600 square foot, $30,000 structure.

[2] Amortized at 7 percent over 30 years.

[3] Based on an estimate of $1.50 per square foot for a 1600 square foot, $30,000 structure.

Economic Feasibility

When a new structure is elevated to some higher elevation, damage is reduced by eliminating damage which otherwise would occur below the elevated elevation. At a lower elevation damage would occur when inundated by less frequent floods, while at a higher elevation these floods would not cause damage if they are below the raised height. Damage reduced is the difference in damage with and without the structure elevated. The without condition depends upon local regulation of flood plain land. In the absence of any regulations a property owner may choose to locate a structure at any flood plain elevation desired. Under the National Flood Insurance Program new structures are required to locate at or above the 100 year flood elevation. The without condition elevation then is based upon one of these two conditions, or some other conditions, if for example a variance were granted. The with condition elevation is the elevation to which the new structure is being raised. Economic feasibility is determined by comparing damage reduced by raising a structure a certain number of feet to the cost to do the raising.

Figures 9-2 through 9-9 show expected annual damage reduced for new type structures raised three feet and five feet respectively. Damage reduced is to structure and contents. These data were computed by first computing expected annual damage at a base elevation (100.0 feet), then computing damage with each structure raised three feet and five feet (103.0 and 105.0 feet respectively). Results of this analysis show damage reduced varies by type structure, flood hazard factor, and location in the flood plain.

The annual cost for raising a structure three feet, expressed as a percentage of structure value (0.5 percent in Table 9-1) is plotted on Figures 9-2 through 9-5. A comparison with damage reduced for each type structure shows that the cost is exceeded for all locations in the flood plain, all flood hazard factors and all type structures.

Costs to raise a new structure five feet are shown in Table 9-1. This value is shown plotted on Figures 9-6 through 9-9. A comparison of cost and damage reduced shows raising five feet to be economically feasible for all locations in the flood plain, all flood hazard factors, and all type structures.

Advantages and Disadvantages

Advantages and disadvantages of elevating new structures on earth fill or columns are presented in Table 9-2 below.

TABLE 9-2

ADVANTAGES AND DISADVANTAGES OF ELEVATING A NEW STRUCTURE

Advantages	Disadvantages
Damage to structure and contents below the elevated elevation is prevented.	Flooding of surrounding areas still occurs with possible damage to other facilities and services, and often making emergency access difficult.
Architectural design, and construction techniques are well known.	
Allows occupancy of flood plain site and use of surrounding infrastructure.	

References

1. U.S. Department of Housing and Urban Development, "Elevated Residential Structures", Federal Insurance Administration, 1977.

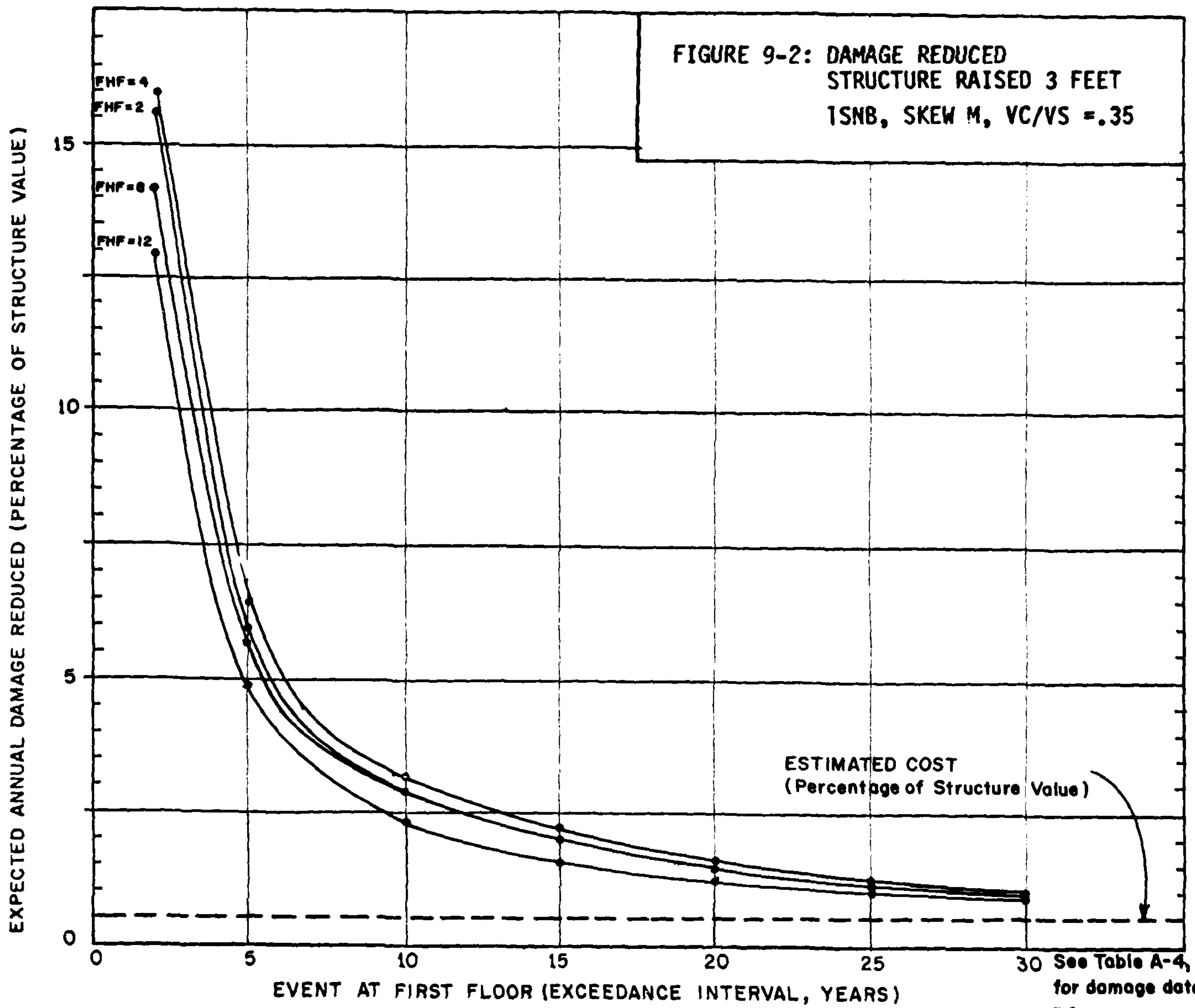


FIGURE 9-2: DAMAGE REDUCED
STRUCTURE RAISED 3 FEET
1SNB, SKEW M, VC/VS =.35

See Table A-4, Appendix A for damage data beyond 30 years.

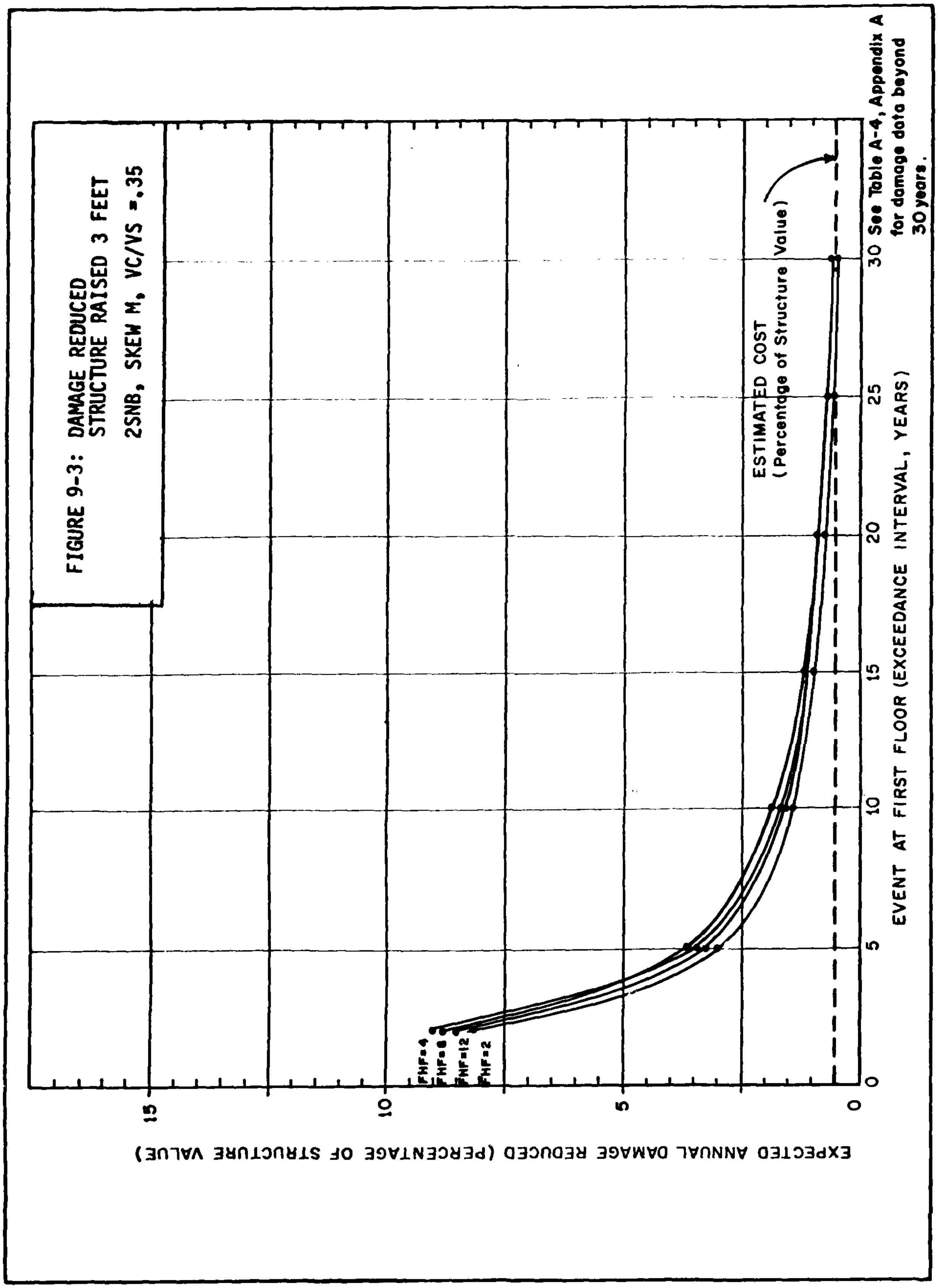


FIGURE 9-3: DAMAGE REDUCED
STRUCTURE RAISED 3 FEET
2SNB, SKEW M, VC/VS = .35

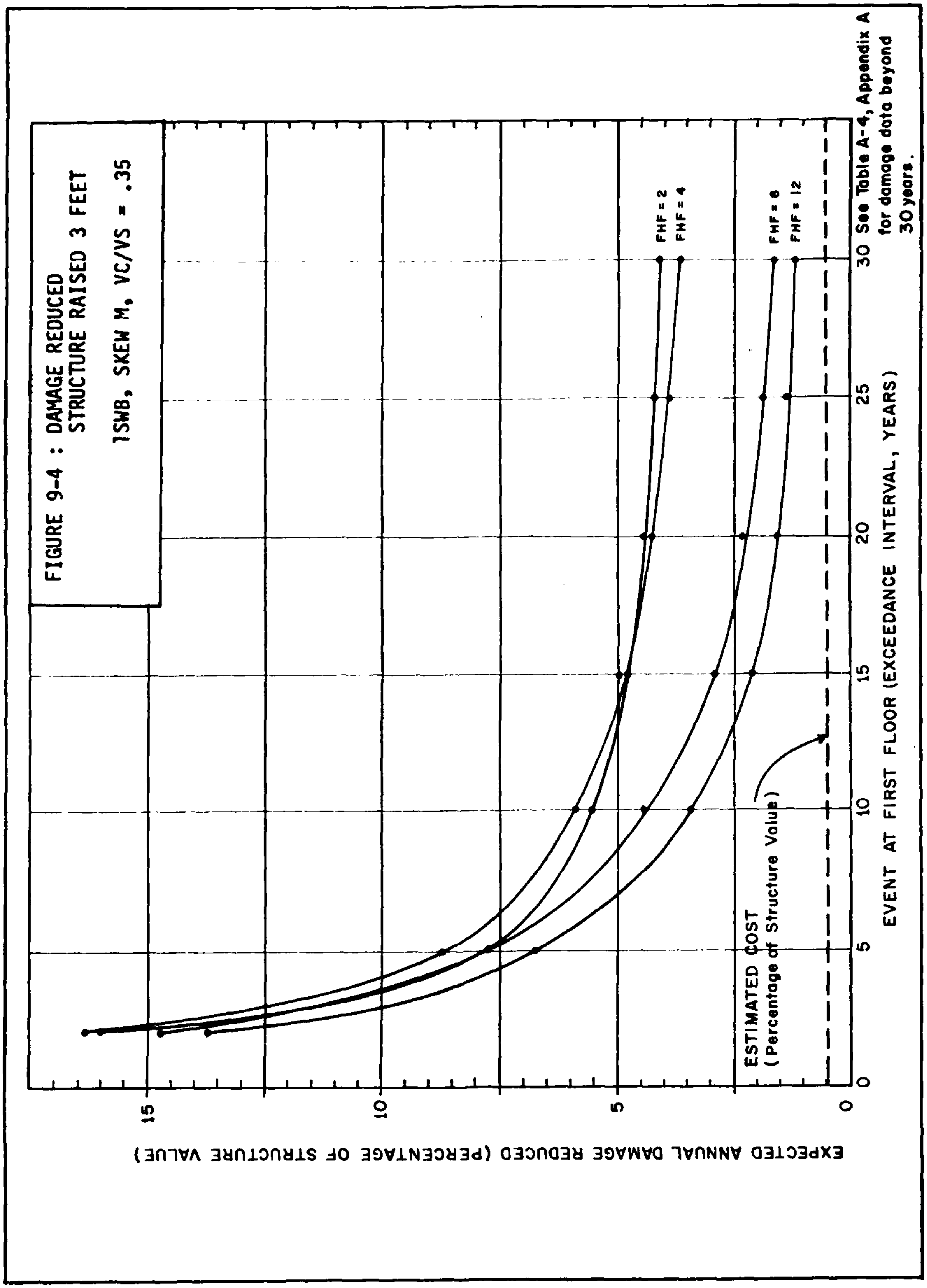


FIGURE 9-4 : DAMAGE REDUCED STRUCTURE RAISED 3 FEET

1SWB, SKEW M, VC/VS = .35

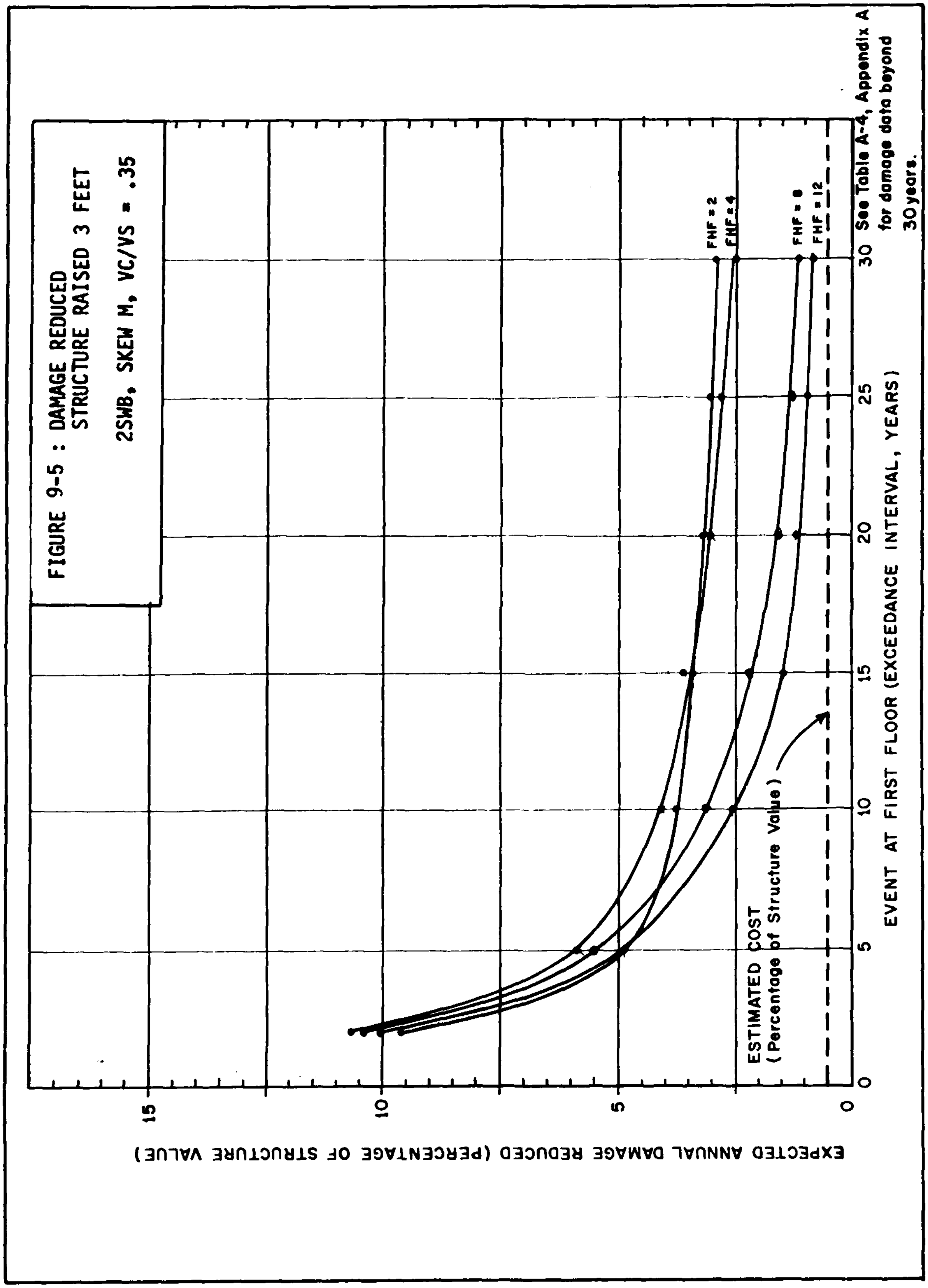


FIGURE 9-5 : DAMAGE REDUCED
STRUCTURE RAISED 3 FEET
2SWB, SKEW M, VC/VS = .35
FHF = 2
FHF = 4
FHF = 8
FHF = 12
See Table A-4, Appendix A for damage data beyond 30 years.
ESTIMATED COST
(Percentage of Structure Value)
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
0
5
10
15
20
25
30

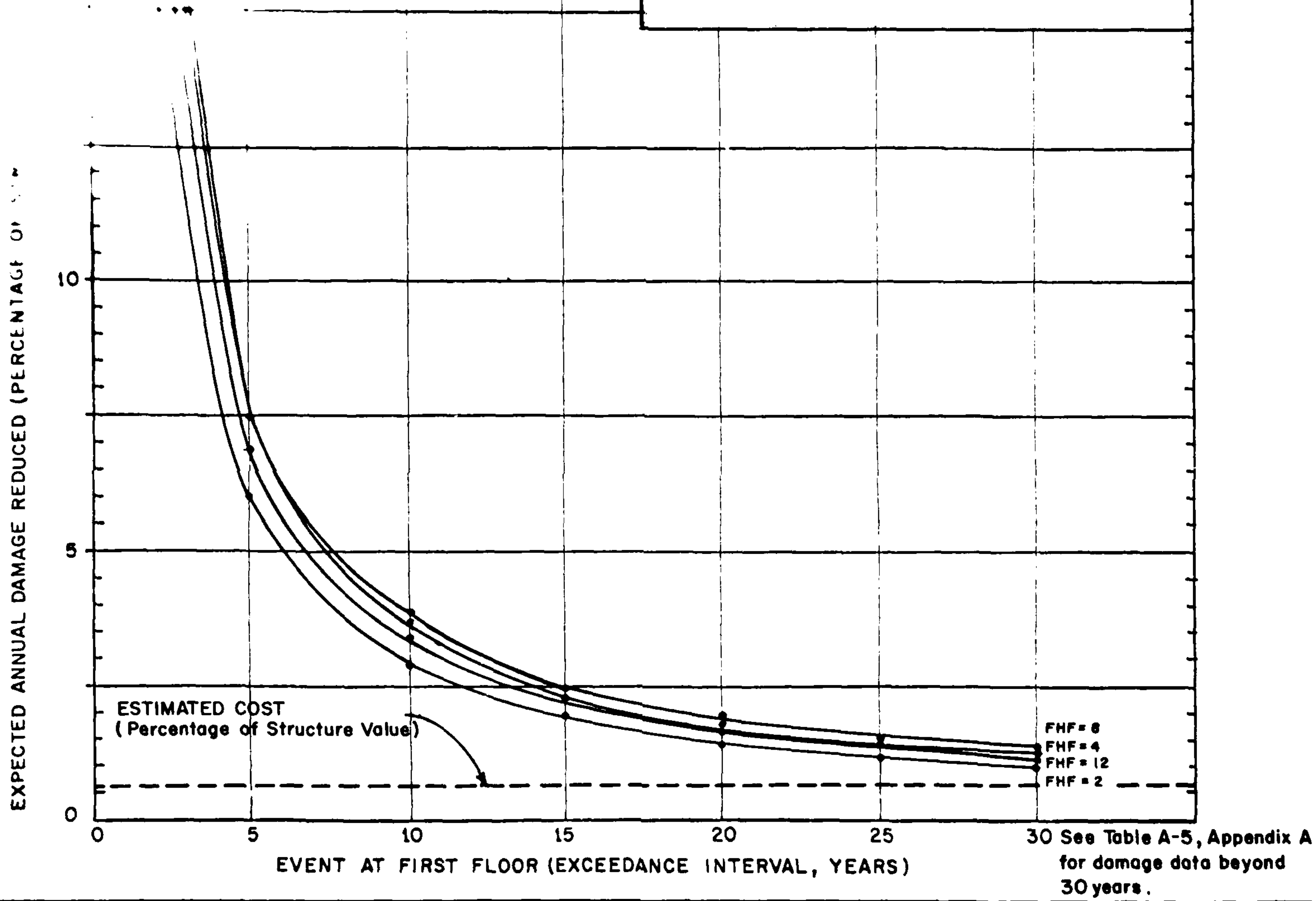


FIGURE 9-6: DAMAGE REDUCED STRUCTURE RAISED 5 FEET

1SNB, SKEW M, VC/VS=.35

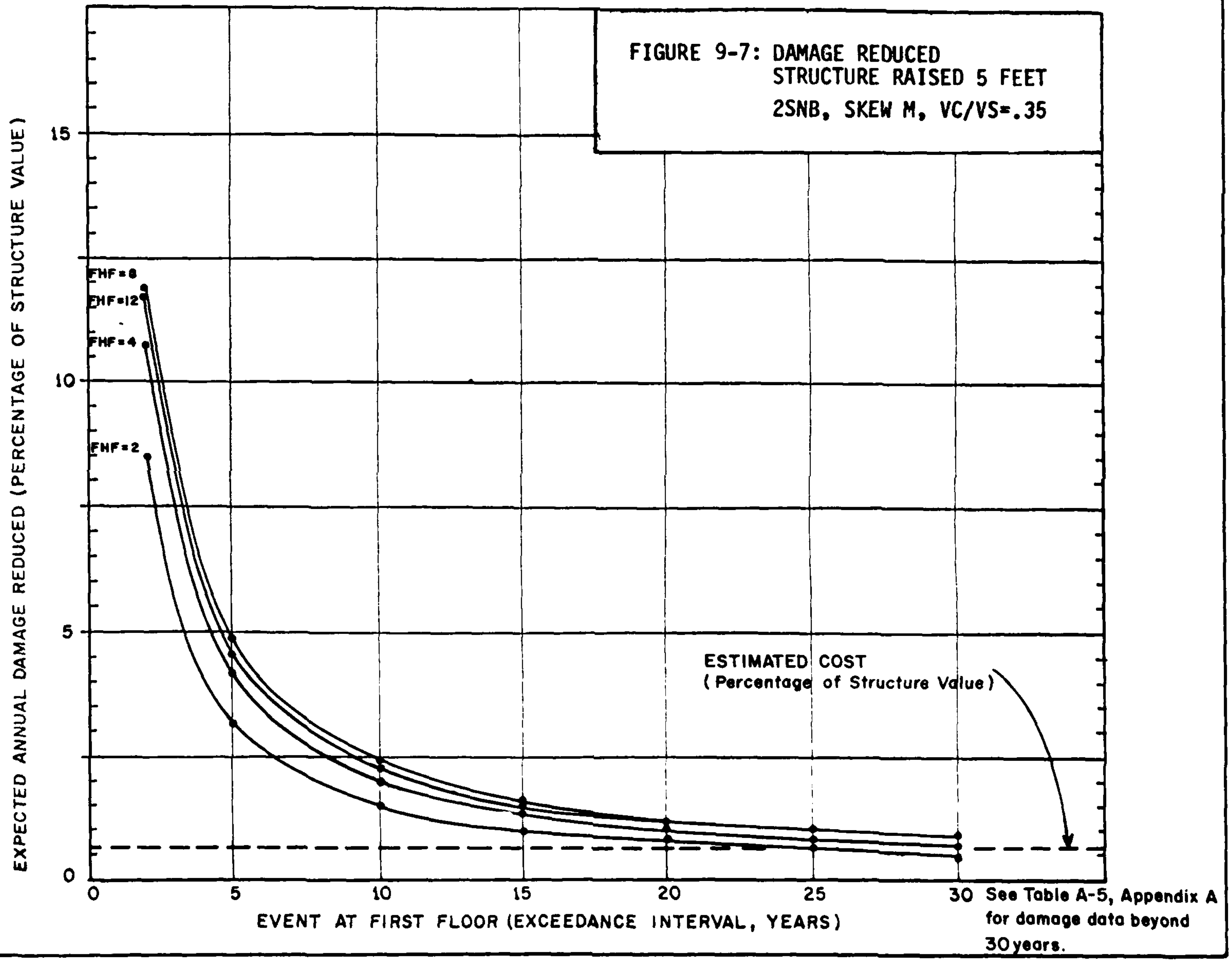


FIGURE 9-7: DAMAGE REDUCED
STRUCTURE RAISED 5 FEET
2SNB, SKEW M, VC/VS=.35

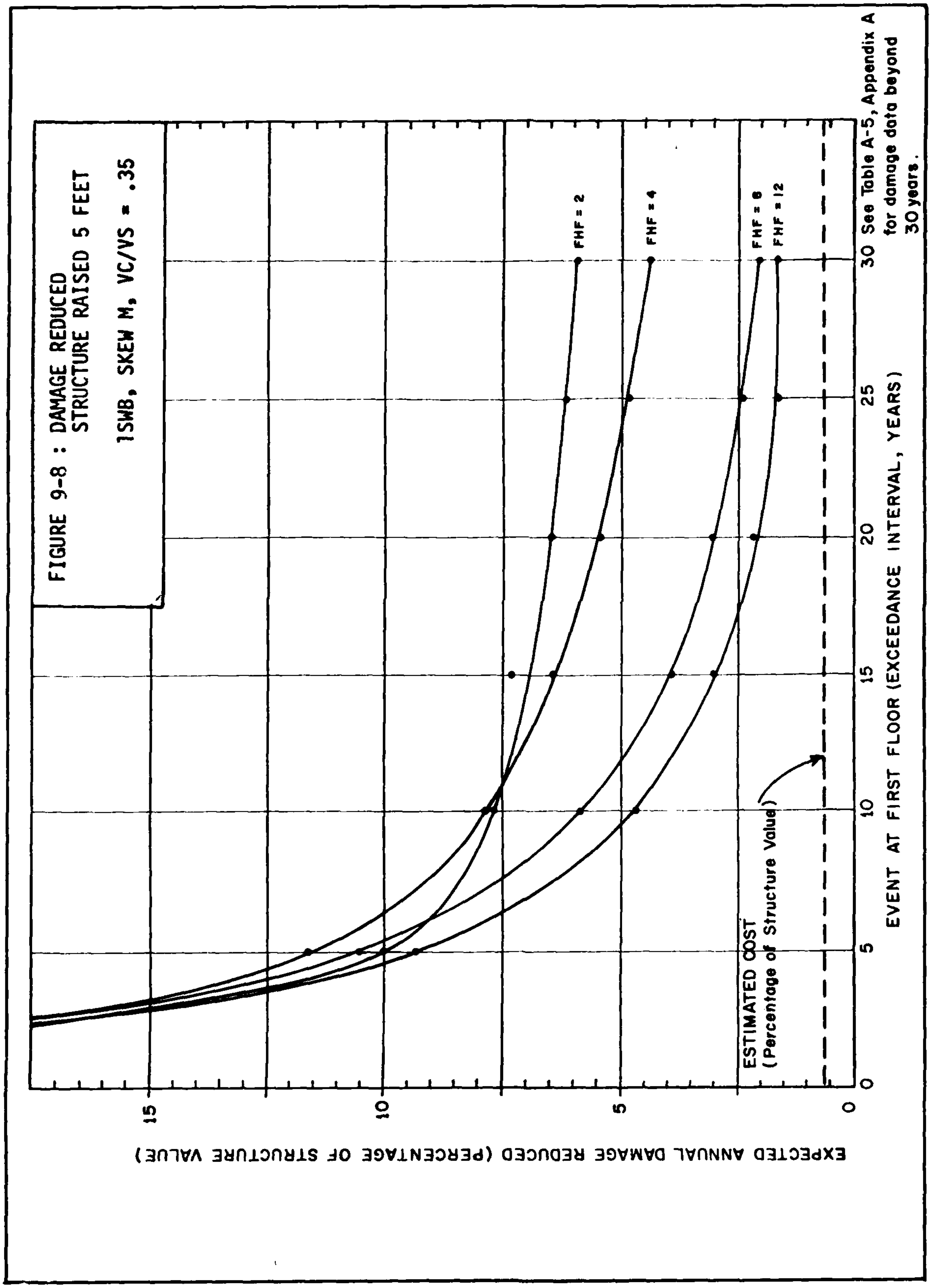


FIGURE 9-8 : DAMAGE REDUCED STRUCTURE RAISED 5 FEET

1SWB, SKEW M, VC/VS = .35

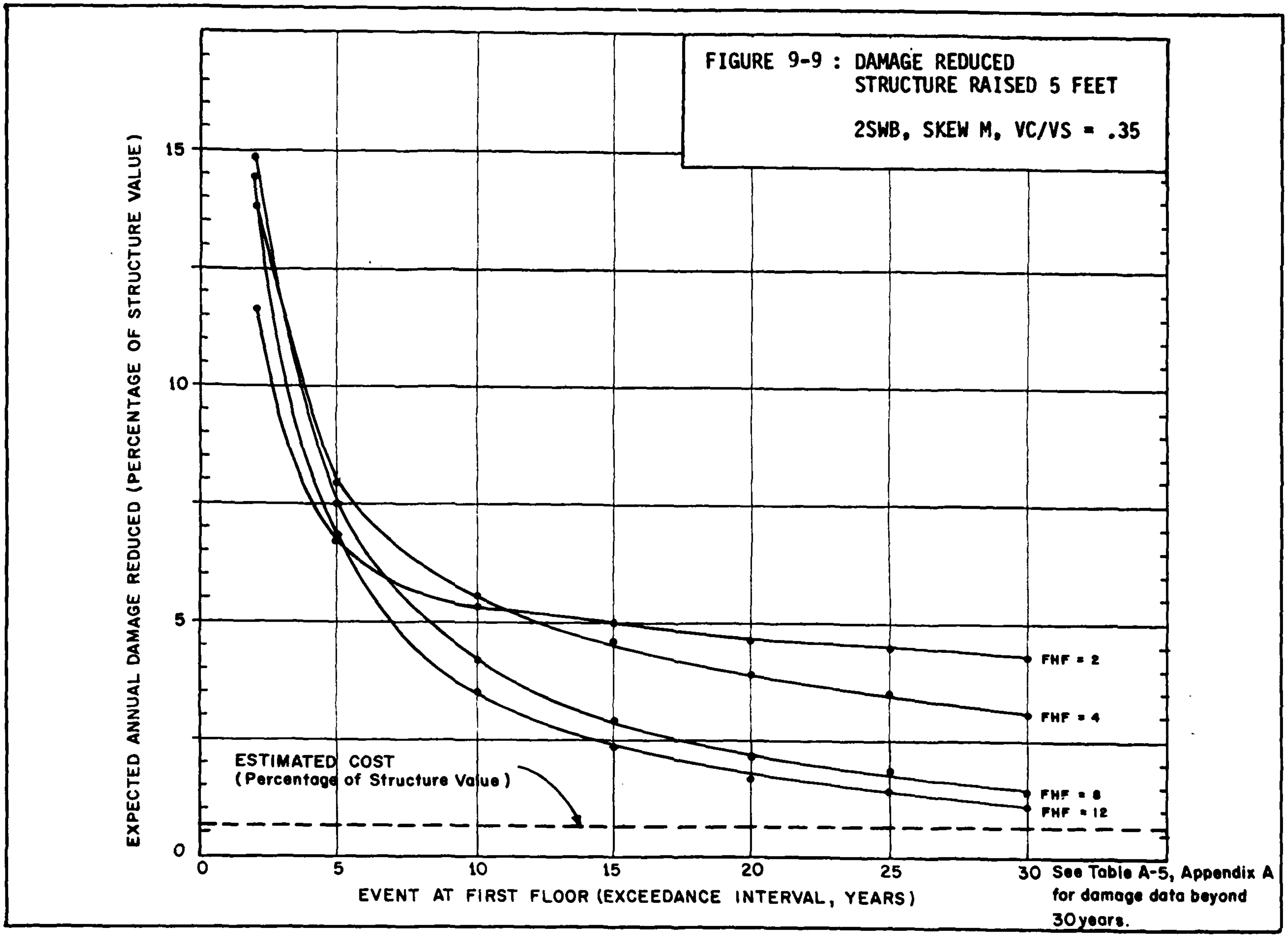


FIGURE 9-9 : DAMAGE REDUCED
STRUCTURE RAISED 5 FEET
2SWB, SKEW M, VC/VS = .35
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
15
10
5
0
0
5
10
15
20
25
30
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)
ESTIMATED COST
(Percentage of Structure Value)
FHF = 2
FHF = 4
FHF = 8
FHF = 12
See Table A-5, Appendix A
for damage data beyond
30 years.

CHAPTER 10

CONSTRUCTION MATERIALS AND PRACTICES FOR NEW OR EXISTING STRUCTURES

Description

When constructing new structures in a flood hazard area or repairing existing structures, water resistant materials and damage reducing construction practices are available to reduce potential damage. Generally, this includes modifying one or more of the following: basement and/or first floor walls, floors, ceilings; structure exterior walls, insulation, outside utilities; and electrical, heating and air-conditioning systems. Specific modifications are described below and in Appendix D.

Basements - The greatest danger to basement walls and floors during flooding is that of collapse. Rising and receeding flood waters can create excessive hydrostatic forces on basement walls and floors causing failure. Several actions can be taken to reduce this danger (Figure 10-1).

- Install drains and valves in the foot of walls so water pressure inside and out will be equalized.
- Use permeable backfill adjacent to walls, floors, and around drains.
- Use water resistant tile, linoleum, carpeting, and plywood.
- Paints and paneling can be of materials which are serviceable after getting wet.
- Basement ceilings can be constructed with drains to allow drainage between framing joists and through the ceiling to prevent excessive weight on the drywall.
- Cabinetry can be of metal or exterior plywood and anchored to walls, floors, or ceilings to prevent flotation.
- Basement stairways can be made wider to facilitate removal of furnishings to higher floors.

First Floor - Paints, paneling, and flooring materials can be selected which are water resistant and serviceable after contact with floodwaters. Cabinets, bookshelves and other furnishings which are susceptible to water damage can be constructed of water damage resistant materials — exterior plywood, metal, or similar materials. Stairways can be made wider to allow movement of furnishings from the first floor to the second floor.

Exterior and Outside - Superstructures and outside tanks can be anchored to their foundations to prevent flotation. A manually operated sewer cutoff valve can be installed in the sewer lateral to prevent backflow from a surcharged sewer. Insulation can be nonabsorbent and all exterior materials can be "exterior grade" to reduce possible water damage. Sub-floor joists and wall studs can also be of lumber which has been treated to repel water.

Electrical, Heating, and Cooling Systems - Actions to reduce water damage to electrical, heating and cooling systems include: anchoring fuel tanks to prevent flotation; venting fuel tanks to the outside atmosphere above the first floor to prevent escape of fuel inside; heating and cooling ducts can be provided with drains; electrical circuits can be separated to allow closing circuits in lower areas while leaving them on in upper areas (this allows utilization of electricity in some

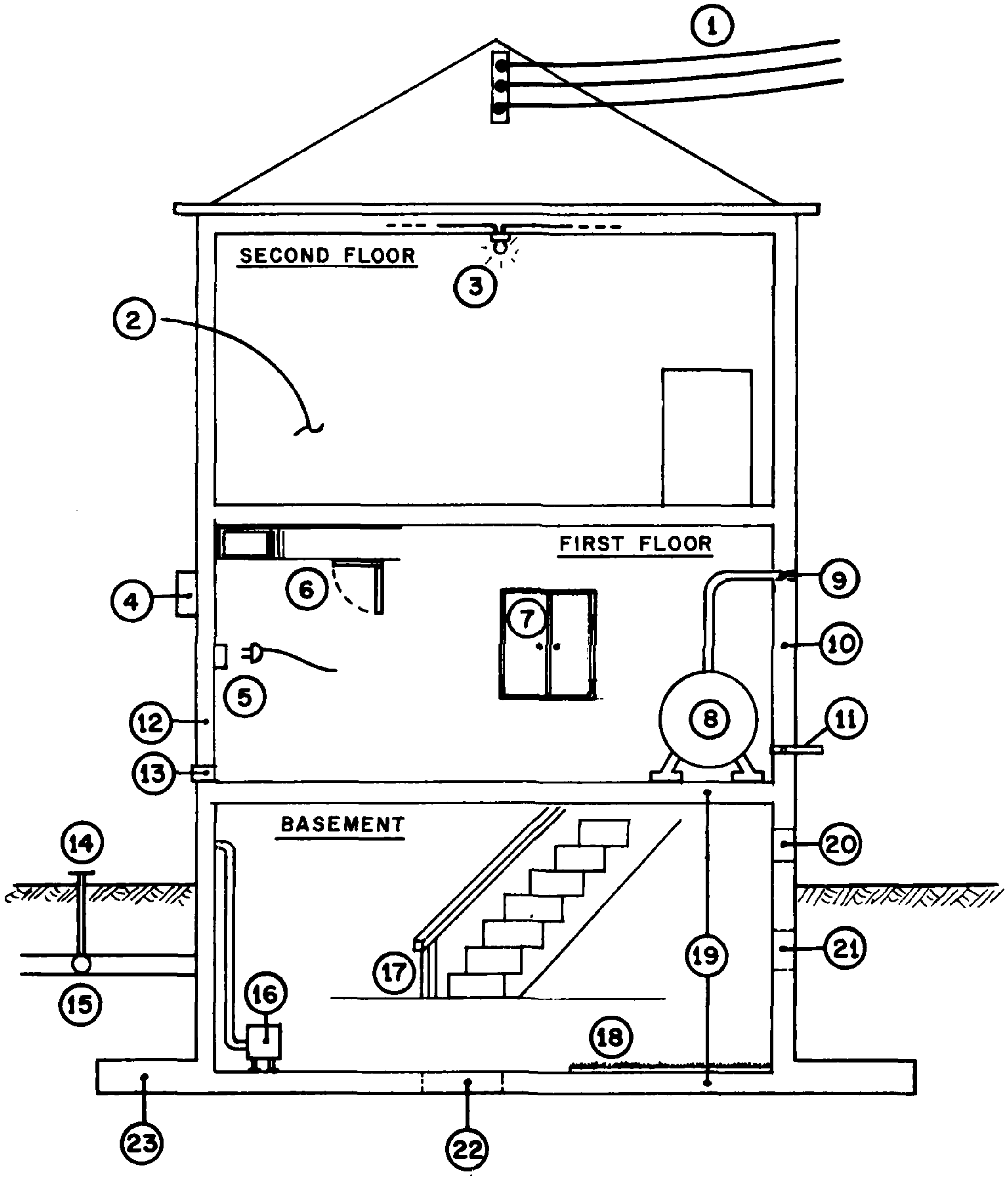


Figure 10-1. Construction Materials and Practices to Reduce Potential Damage.

FIGURE 10-1 LEGEND

CONSTRUCTION MATERIAL AND PRACTICES TO REDUCE POTENTIAL DAMAGE

1. Overhead energy and communications line.
2. Large space for temporary storage of contents during flood hazard.
3. Separate branch circuit above flood water level.
4. Elevated main electrical box.
5. Elevated electrical outlets.
6. Air duct outlet for water drainage.
7. Water damage resistant cabinetry.
8. Anchored tank.
9. Elevated outside vent discharge.
10. Impermeable or damage resistant thermal and acoustical insulation.
11. Temporary outside sink drain with positive valve.
12. Water resistant wall material: polyester epoxy paint, plastic tiles, treated wood beams, etc.
13. Positive drain valve for receding water.
14. Manual control valve.
15. Sewer gate valve.
16. Sump pump for clean-up.
17. Extra wide stairway for rapid content removal.
18. Water damage resistant carpeting.
19. Water damage resistant floor finish: linoleum, rubber, vinyl.

20, 21, 22. Weakened basement window, wall, and floor respectively, to allow entrance of water to equalize the hydrostatic pressure which could cause structural damage.

23. Anchorage of foundation to prevent flotation and/or overturning.

parts of the structure while other parts are flooded); and gas piping can be sloped and fitted with a drain plug to allow drainage.

Physical Feasibility

The actions described in this Chapter are generally applicable to all structures to one degree or another and in some combination. Their application is site specific and will depend upon the type of structure and contents, the nature of the flood hazard, and upon the availability of other alternatives. They appear to be most appropriate in situations where flooding is not severe or where it is the only feasible alternative — physically or economically. It is likely these actions will find their greatest application as requirements in local building codes or in other building regulations, and in combination with other measures.

Costs

Costs of implementing the actions associated with this measure vary with the actions taken, but generally are low because they can be done as part of new construction, remodeling or repair. The Federal Housing Administration has collected nationwide cost information and have found that first costs range from practically nothing to 2.5 percent of the structure value (1, 2). Often the cost is less than 1.0 percent. Assuming a $30,000 structure and amortizing this first cost at 7 percent for 30 years yields annual costs as percentage of structure value of 0.2 and .08 percent for 2.5 and 1.0 percent first costs respectively. This is low and makes it an attractive possibility in situations where available funds are limited.

Economic Feasibility

Computation of damage reduced should be based upon estimates of damage with and without a particular water resistant material or damage reducing construction practice. This is difficult to determine since damage is not eliminated, as it would be if some property were removed, but is simply reduced. A proper estimate of this reduction must consider each action and what damage would be likely with and without that action. Expected annual damage reduced would be computed in the traditional manner by weighting the damage computed with and without, by its probability of occurrence. No estimates of damage reduced were made in this study, although it is felt most actions would be economically feasible because of the low additional cost of implementation in new construction.

Advantages and Disadvantages

The advantages and disadvantages of using construction materials and practices which recognize a flood hazard are similar to those mentioned in Chapter 6 on rearranging damageable property within a structure. Table 10-1 summarizes these items.

TABLE 10-1

ADVANTAGES AND DISADVANTAGES OF USING CONSTRUCTION MATERIALS AND PRACTICES TO REDUCE DAMAGE

Advantages	Disadvantages
All residential, commercial and industrial property owners can do this to one degree or another.	Flooding will still occur causing residual damage and necessitating clean-up and restoration.
It can be done on a selective basis to modify that property which is susceptible to damage.	Damage will be reduced only where more appropriate construction materials and practices are used.
Damage will be reduced because of the actions taken.	
Many actions require little or no increase in cost.	

References

1. Personal communication from D. Earl Jones, Jr., Federal Housing Administration, Department of Housing and Urban Development, 1977.

2. Jones, D. Earl, Jr., "Flood Proofing Limitations and Flood Loss Mitigation" and "The Economics of Water-Resistant Construction"; Proceedings of a Joint ASCE/Engineering Foundation Conference on Flood Proofing and Flood Plain Management, 1977.

CHAPTER 11

ZONING ORDINANCES, SUBDIVISION REGULATIONS, AND BUILDING AND HOUSING CODES

Description

Through proper land use regulation, flood plains can be managed to insure that their use is compatible with the severity of a flood hazard. Several means of regulation are available and three will be discussed in this chapter: zoning ordinances, subdivision regulations, and building and housing codes. Their purpose is to reduce losses by controlling future use, and changes in existing use, of flood plain lands.

The following descriptions are taken from the Water Resources Council's study on "Regulation of Flood Hazard Areas to Reduce Flood Losses" (Part 1, page 16, Volume I).

Zoning - "Zoning involves the division of a governmental unit into districts and the regulation, within these districts, of: (1) the use of structures and land; (2) the height and bulk of structures; and (3) the size of lots and density of use. The characteristic feature of zoning that distinguishes it from other police power controls is that the regulations differ from district to district. For this reason it can be used to set special standards for land uses in flood hazard areas. The division into districts of lands throughout a community is usually based upon some broad land use plan to guide the growth of the community." See Figure 11-1.

"The flood plain regulations contained in a zoning ordinance, much like the other operative ordinance provisions, consist of two parts: (1) a written text which sets forth the regulations which apply to each district together with administrative provisions; and (2) a map delineating the boundaries of the various use districts. The important aspect of zoning is that it can be used to regulate what uses may be conducted in flood hazard areas, where specific uses may be conducted, and how uses are to be constructed or carried out. Zoning can be used to restrict riverine or coastal areas to particular uses, specify where the uses may be located, and establish minimum elevation or floodproofing requirements for the uses." See Figure 11-2 for an example zoning ordinance.

Subdivision Regulations - "Subdivision regulations guide the division of large parcels of land into smaller lots for the purpose of sale of building development. The regulations require that the subdivider prepare a plat — a detailed map of the proposed subdivision land. The plat must be approved by the local regulatory agency, usually the planning board, before the plat is recorded and lots are sold. The agency checks the plat for compliance with subdivision regulations, the local master plan, the zoning ordinance, and other regulations. A proposed subdivision plat is typically reviewed to determine the adequacy of the street system; length of depth of blocks; width and length of lots; provision for parks and open spaces; sufficiency of water and sewerage systems; adequacy of drainage; safety from flood or other hazards; and additional specifications set forth in the ordinance. Subdivision regulations with special reference to flood hazards often (1) require installation of adequate drainage facilities, (2) require that location of flood hazard areas be shown on the plat, (3) prohibit encroachment in floodway areas, (4) require filling of a portion of each lot to provide a safe building site at elevation above selected flood heights or provide for open support elevation to achieve the same ends, and (5) require the placement of streets and public utilities above a selected flood protection elevation. Figure 11-3 shows an example of a subdivision regulation.

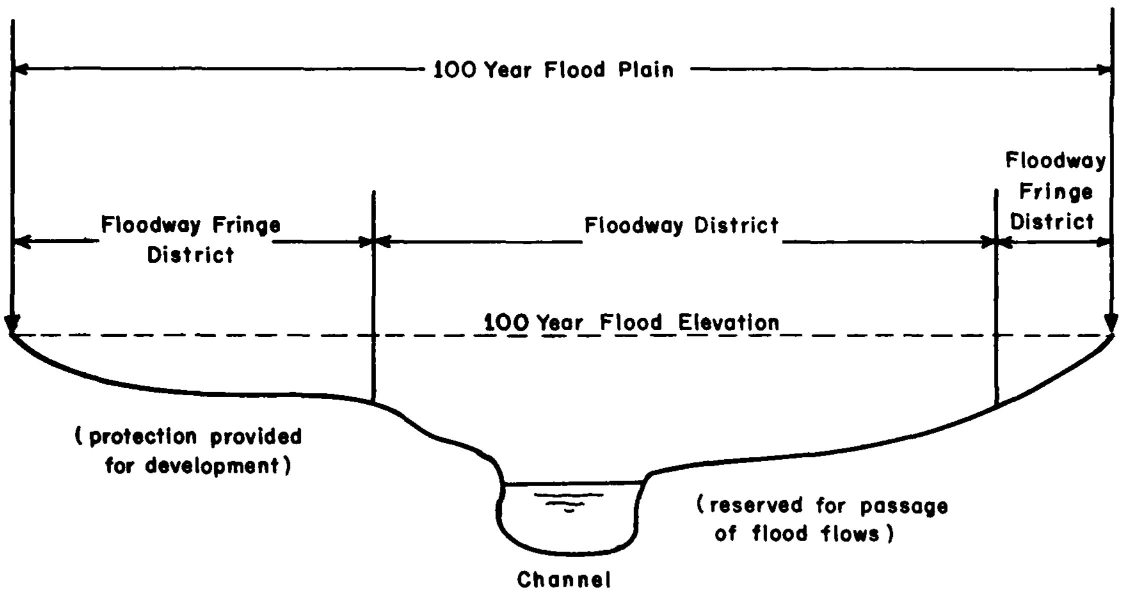


Figure 11-1. Zoning Districts

SECTION 3.0 ESTABLISHMENT OF ZONING DISTRICTS

The flood plain areas within the jurisdiction of this ordinance are hereby divided into the two districts: Floodway Districts (FW) and Floodway Fringe Districts (FF). The boundaries of these districts shall be shown on the Official Zoning Map. Within these districts all uses not allowed as Permitted Uses or permissible as Special Exception Uses shall be prohibited.

SECTION 4.0 FLOODWAY DISTRICT (FW)

4.1 PERMITTED USES

The following uses having a low flood damage potential and not obstructing flood flows shall be permitted within the Floodway District to the extent that they are not prohibited by any other ordinance and provided they do not require structures, fill or storage of materials or equipment. But no use shall adversely affect the capacity of the channels or floodways of any tributary to the main stream, drainage ditch, or any other drainage facility or system.

4.11 Agricultural uses such as general farming, pasture, grazing, outdoor plant nurseries, horticulture, viticulture, truck farming, forestry, sod farming, and wild crop harvesting.

4.12 Industrial-commercial uses such as loading areas, parking areas, airport landing strips.

4.13 Private and public recreational uses such as golf courses, tennis courts, driving ranges, archery ranges, picnic grounds, boat launching ramps, swimming areas, parks, wildlife and nature preserves, game farms, fish hatcheries, shooting preserves, target ranges, trap and skeet ranges, hunting and fishing areas, hiking and horseback riding trails.

4.14 Residential uses such as lawns, gardens, parking areas and play areas.

SECTION 5.0 FLOODWAY FRINGE DISTRICT (FF)

5.1 PERMITTED USES

The following uses shall be permitted uses within the Floodway Fringe District to the extent that they are not prohibited by any other ordinance:

5.11 Any use permitted in Section 4.1.

5.12 Structures constructed on fill so that the first floor and basement floor are above the regulatory flood protection elevation. The fill shall be at a point no lower than ________ ft. below the regulatory flood protection elevation for the particular area and shall extend at such elevation at least ________ feet beyond the limits of any structure or building erected thereon. However no use shall be constructed which will adversely affect the capacity of channels or floodways of any tributary to the main stream, drainage ditch, or any other drainage facility or system.

Figure 11-2. Zoning Ordinance (Reference 1)

ARTICLE I
SCOPE AND PURPOSE

A. Scope of Regulations

These Regulations prescribe the procedures for the subdivision of land within the unincorporated area of the County and any other area of the County made subject thereto under the provisions of Sections . . . . and comprise the requirements, standards, and specifications with respect to:

1. The proper location and width of streets, building lines, open space, recreational areas, and public lands.

2. The avoidance of conditions that would lead to the creation of blighted areas.

3. The avoidance of overcrowding of population and congestion of vehicular traffic.

4. The manner in which streets are to be graded and improved, and the extent to which water, sewer, storm water, and other utility services are to be provided.

* * * * * * * * * * *

B. Interpretation

These Regulations are intended as MINIMUM REQUIREMENTS to provide for the coordinated, efficient and economic development of the County, to insure the adequacy of street and utility facilities, and to promote the public health, safety, and welfare.

* * * * * * * * * * *

D. Suitability of Land for Subdivision Development

Land unsuitable for subdivision development due to drainage, flooding, steep slope, rock formation or any other condition constituting a danger to health, life, or property shall not be approved for subdivision.

* * * * * * * * * * *

ARTICLE II
DEFINITIONS

For the purpose of these Regulations, the terms used herein are defined as follows:

* * * * * * * * * * *

Flood Hazard Area: All land subject to periodic inundation from overflow of the 100 year flood on natural waterways as calculated by approved engineering methods.

* * * * * * * * * * *

ARTICLE IV
MINIMUM STANDARDS OF DESIGN

* * * * * * * * * * *

C. Lots

* * * * * * * * * * *

2. Each lot shall contain a building site completely free from the danger of flooding. No lot shall be impractical of improvement due to steepness of terrain, dangerous soil conditions, or other adverse natural physical condition.

* * * * * * * * * * *

E. Utility and Drainage Easements

* * * * * * * * * * *

3. Whenever a stream or important surface drainage course is located in an area proposed for subdivision, the subdivider shall provide an adequate easement and facilities to prevent flooding or erosion along each side of the stream . . . . The subdivider may be required to enlarge the existing drainage channel at the time of construction.

Figure 11-3. Subdivision Regulation (Reference 2)

same ends, and (5) require the placement of streets and public utilities above a selected flood protection elevation. Figure 11-3 shows an example of a subdivision regulation.

Building and Housing Codes - "Building codes neither regulate where development takes place nor the type of development, but rather building design and materials. Building codes can reduce flood damages to structures by setting specifications to: (1) prevent flotation of buildings by requiring proper anchorage, (2) establish minimum floor level elevations consistent with flooding potential, (3) restrict use of materials which deteriorate when exposed to water, and (5) require structural design consistent with water pressure and flood velocities. General floodproofing requirements are sometimes placed in flood plain zoning ordinances rather than building codes in the form of general performance standards which give the developer an option of elevating his structure to a safe height. Housing codes, like building codes, set minimum standards for construction but also set minimum standards for maintenance of structures. These can be used to require repair of flood damaged structures to assure the safety of occupants and prevent blighting." For an example building code see Figure 11-4.

Physical Feasibility

Zoning ordinances, subdivision regulations, and building and housing codes are generally feasible for any flood plain land, whether the land is occupied by residential, commercial, or industrial type structures, or by nonstructures such as golf courses and playgrounds. While there are no general limitations, a regulatory program is developed and administered for a specific piece of land in a specific community and state, thus, when developing such regulations at the local level some very real restrictions may develop. Several considerations are discussed in the Water Resources Council's "Regulation of Flood Hazard Areas to Reduce Flood Losses" (1). These considerations are summarized below.

- Regulatory programs to reduce flood losses vary. This variation depends upon the level at which regulation occurs (State, local or both), the objectives and specific regulatory policies, and the regulatory tools chosen to implement objectives. Variations may also reflect differing State Supreme Court attitudes to the legality of specific regulatory approaches.
- The 14th Amendment of the United States Constitution and similar provisions in state constitutions require that police power regulations be reasonable, related to regulatory objectives and afford equal treatment to similarly situated individuals.
- Flood plain regulations are subject to the same general legal requirements as other land use controls.
- The power to regulate flood plain land uses must be found in the general or special language of enabling statutes.
- Courts generally determine only the specific constitutionality of enforcing land use regulations against a complaining landowner and not the general constitutionality of regulations applied to all landowners.
- Widespread judicial support can be found for regulations which require that those who use lands be responsible for actions which substantially harm public or private interests.
- Flood plain regulations must be based upon sound data to meet constitutional requirements.

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PHYSICAL AND ECONOMIC FEASIBILITY OF NONSTRUCTURAL FLOOD PLAIN --ETC(U)

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23.13.070 Flood-proof Construction. All buildings and utility systems, including private water and sewage systems, shall be of flood-proof construction or adequately protected from flood damage in accordance with the following standards adopted by the City of Richland:

a. The State of Washington Flood Control Map entitled, "Yakima River, Washington, Flood Plain, Information Study, Richland, Washington, 100 Year Flood Elevation, Yakima River, Miles 6.5–9.5," as modified by the Division of Flood Control, and dated July 2, 1964, together with all explanatory matter thereon, is hereby adopted by reference and declared to be a part of this ordinance. Said map, together with all explanatory matter thereon, shall be on file in the office of the City Clerk.

b. For all permitted occupancies other than Group J as defined in the latest edition of the Uniform Building Code as adopted by the City:

1. All footings shall be of poured-in-place concrete, shall be a minimum width of 16" and 8" in depth, shall rest on undisturbed earth, and the bottom of such footing shall be a minimum of 24" below finished grade.

2. Perimeter foundation walls shall be of poured-in-place concrete, a minimum of 8" in thickness and shall be either (a) poured continuous with the footings, (b) keyed with keying in footing 1½" deep and 3" wide, or (c) doweled to footing with No. 5 re-bar, 12" long spaced no farther apart than 2' around the perimeter of the building.

3. Such perimeter foundation walls shall extend a minimum of 2' above the 50 year flood level for the particular location of the building as established by the State of Washington Division of Flood Control. In no case shall the bottom of the first floor joists be lower than the minimum elevation for top of foundation.

4. All interior bearing walls and piles below the established minimum top of foundation shall be of masonry construction.

5. All electrical wiring, outlets or devices shall be above the said minimum elevation for top of foundation or of approved underground construction.

6. No furnace fire pot or furnace controls shall be lower than the minimum top of foundation as established above.

7. A backwater valve shall be installed in the sewer line or lines in an accessible location immediately adjacent to the exterior foundation wall.

Figure 11-4. Building Code (Reference 1)

- Flood plain regulations often provide for general rules which apply to all uses and additional case-by-case evaluation of certain special uses.
- Whenever possible, flood plain regulations should be part of comprehensive water and related land use management programs.
- Regulations must balance private and public rights to withstand attacks that the regulations "take" private property without payment of just compensation.
- Adoption, administration, and enforcement are essential steps for successful flood plain regulation programs.

In addition to the above, regulations must be flexible and fair. Procedures for amendments and variances are necessary and can be provided by establishing criteria for special use permits. Also, regulations must be designed to prevent public harm rather than serving public benefits.

Costs

Costs associated with preparing, adopting and administering zoning ordinances, subdivision regulations, and building and housing codes include:

- Costs of obtaining basic engineering data.
- Costs to draft and adopt a regulation.
- Costs to administer a regulation.
- Possible loss of tax revenue.

Costs of obtaining basic engineering data may be the major cost item for some communities. While the present Federal programs are making these data available at no cost to local governments, it will probably be many years before they can provide data for all communities. In addition, communities are expanding beyond the limits of the present studies and new communities are being established. Where communities must obtain their own data the cost could be considerable depending upon the size of the flood plain and hazard condition.

Model ordinances are readily available to guide preparation of specific community regulations. Also, guidance and assistance is available from Federal agencies at no cost. For these reasons the cost of actually drafting the regulations is sometimes relatively low and handled as a normal staff function. Public and other meetings must be held for adoption and these costs must also be included.

Costs to administer a regulation can be major or minor depending upon the "interest". Flood plain land not subject to the development pressures of urban areas would probably have a negligible administration cost. As development pressure increases administration is likely to be more costly and time consuming as "interest" increases and individuals and groups request and appeal for variances.

Another possible cost is loss of tax revenue. This loss is measured as the difference in the tax revenue with and without the regulation. In most situations this loss will be small or insignificant because development locating elsewhere in the area will transfer the higher evaluations with no loss of revenue to the municipality. In some situations the flood plain may be the last area of land, and utilizing it for a higher taxable use will increase tax revenues, and regulating it would cause a loss of such revenues. Estimates must be made on a site by site basis.

Economic Feasibility

Damage reduced through the use of zoning ordinances, subdivision regulations, and building and housing codes is measured as the difference in damage with and without implementation of the ordinance, regulation, or code. Since these regulatory means are directed principally toward future development, the with condition must be estimated based on a judgement as to how much, what type, and how future development will be affected. This can only be done by evaluating each individual flood plain and community. In this study no attempt was made to estimate damage reduced. In general, it is felt that if the necessary basic engineering data is available or can be obtained at a reasonable cost, and there will not be a significant loss of tax revenue, then all of these regulatory means will prove economically feasible.

Advantages and Disadvantages

Table 11-1 summarizes the major advantages and disadvantages of zoning, regulations, and codes.

TABLE 11-1

ADVANTAGES AND DISADVANTAGES OF ZONING ORDINANCES, SUBDIVISION REGULATIONS AND BUILDING AND HOUSING CODES

Advantages	Disadvantages
An effective means of bringing about the proper use of flood plain lands. Economic, environmental, and social values can be integrated with the recognized flood hazard.	Not effective in reducing flood damage to existing structures.
Helps to keep flood damage from increasing. By addressing non-conforming uses they can be helpful in achieving the necessary land use adjustments to mitigate existing flood problems.	Subject to variance or amendment by local governmental bodies which can reduce effectiveness considerably.
Can be effective over time on existing improper development, or additions and modifications to existing property.	Tend to treat all flood plain property equally when in fact various economic factors may make one type of development more appropriate for one portion of the flood plain and another type more appropriate elsewhere.

References

1. U.S. Water Resources Council, "Regulation of Flood Hazard Areas to Reduce Flood Losses", Volume 1, Parts I - IV and Volume 2, Parts V - VI, 1971.

2. U.S. Army Engineers, "Guidelines for Flood Damage Reduction", Pamphlet prepared by the Sacramento District, 1976.

3. U.S. Army Engineers, "A Perspective on Flood Plain Regulations for Flood Plain Management", Engineering Pamphlet 1165-2-304, 1 June 1976.

CHAPTER 12

PUBLIC ACQUISITION OF FLOOD PLAIN LAND

Description

Public acquisition of flood plain land is commonly of two types, (1) acquisition of full fee title, and (2) acquisition of land use easement. Fee acquisition transfers ownership from private to public hands and thereby permits use for public purposes which presumably will be compatible with the flood hazard (Figure 12-1). Preservation of open space and development of parks are two common public uses for flood plain land acquired in fee. Acquisition in fee is most appropriate for undeveloped land or land with few structures or other facilities. For highly developed land the presence of existing structures can make acquisition much more costly and at the same time may not control development. Measures for this situation are discussed in Chapter 7 which deals with removal of existing structures and/or contents from a flood hazard area.

Acquisition of a land use easement is intended to reduce flood damage by restricting land use which is incompatible with the flood hazard. This generally means restrictions on building and filling in the flood plain. Ownership, use, access, and sometimes occupancy are maintained by the owner, but use is restricted to the conditions of the easement. Some easements specify continuation of present uses; still others specify open type uses and list permissible types. Figure 12-2 illustrates this measure

Acquisition in fee or easement need not be immediate, but may be gradual over time. Community contributions to loss restoration can be made contingent upon public title or easement, or acquisition can be made a continuing part of a community development program.

Physical Feasibility

Land acquisition is physically feasible for any flood plain land which can legally be purchased, or for which an easement can be obtained. Whether or not acquisition is used as a means to reduce future flood losses is usually dependent upon identifying other needs for the land. Public bodies have needs for land for a variety of purposes and wise planning can lead to acquisition for purposes which are compatible with the flood plain. For example, land for recreation, open space, or wild life preservation. Planning community land use in this way achieves two objectives — a need is met and future flood damage is reduced.

Another need which can be met by acquisition is preservation of natural flood plain storage. Loss of channel cross-section storage by encroachment of development can cause increases in flood stage at the site and higher peak flow downstream. While the Flood Insurance Program restricts this in communities under the Program there can be flood plain lands upstream, perhaps outside a community, which serve as valuable storage areas. Acquisition can be used to preserve this storage and at the same time control future development.

Acquisition has been used in those situations where flood hazard land is available (generally undeveloped) and there is a need for that type of land for another community purpose, and where it it necessary to preserve natural valley storage to prevent future increases in stage or flow. References 1, 2 and 3 discuss the problems and trade-offs of acquisition in three river basins in the eastern United States.

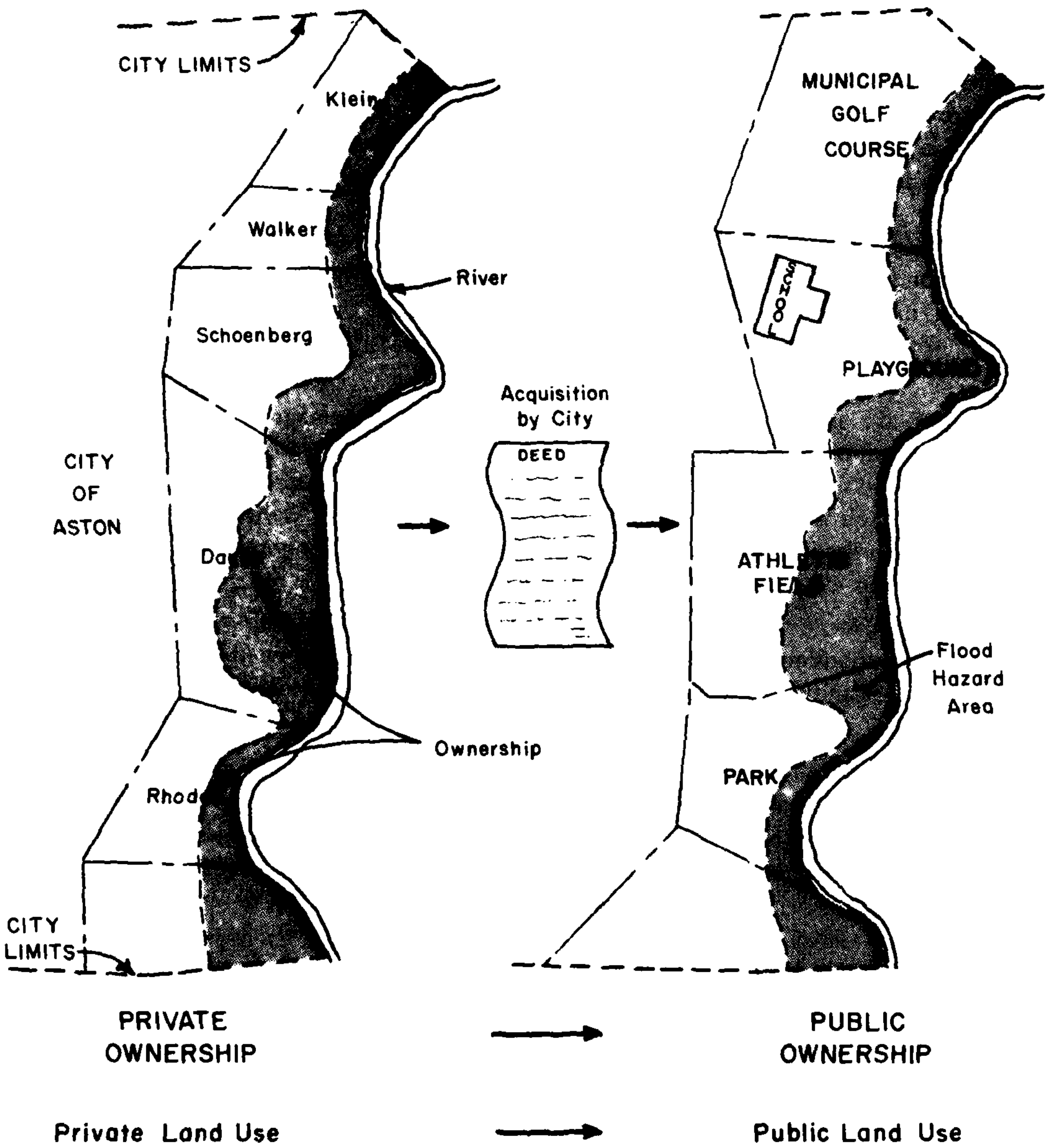


Figure 12-1. LAND ACQUISITION

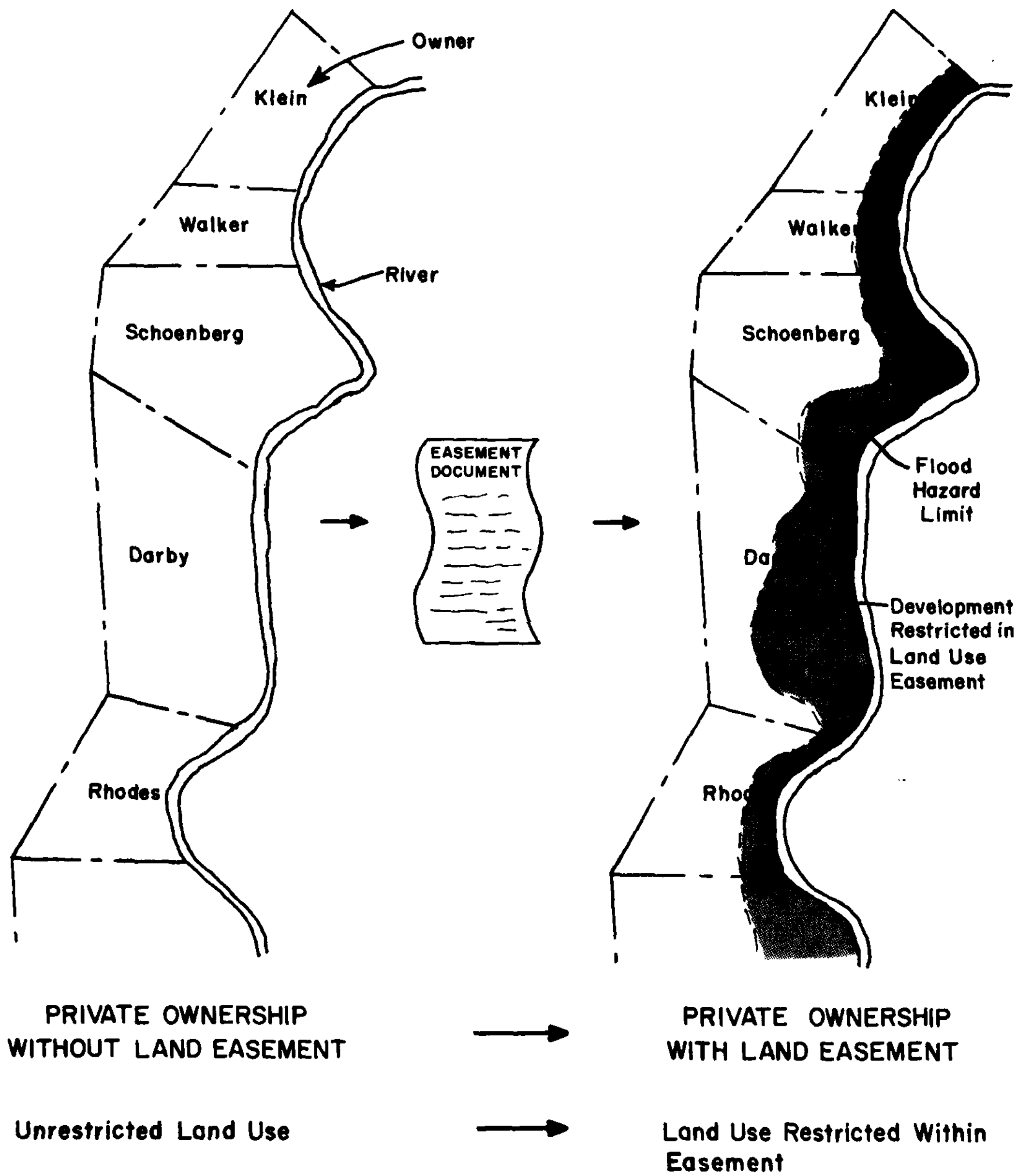


Figure 12-2. LAND EASEMENT

Costs

Costs of acquisition in fee or easement depend upon the cost per acre and number of acres needed. Both items are highly variable and must be determined on a case by case basis. Per unit costs can vary considerably within a community, between communities, and regionally. The number of acres needed depends upon the plan — it may require a few acres or thousands of acres. Administrative costs — costs to acquire land — are generally small compared with the cost of the land or easement itself.

Economic Feasibility

Acquisition, either by fee or easement, reduces damage by controlling future use. With acquisition there will, hopefully, be less damageable property exposed to the flood hazard than without. The difference in damage with and without will measure the damage reduced. The accuracy of this measurement is tied to the accuracy of estimating future land use for both conditions. This can best be done for specific flood plains. No attempt was made in this study to estimate damage reduced on a general basis.

Advantages and Disadvantages

Several advantages and disadvantages of acquisition are summarized in Table 12-1.

TABLE 12-1

ADVANTAGES AND DISADVANTAGES OF THE USE OF PUBLIC ACQUISITION OF FLOOD PLAIN LAND TO REDUCE FLOOD DAMAGE

Advantages	Disadvantages
Provides control of land and its use with fee title.	Does not reduce existing damage.
Provides control of certain land uses with an easement, but without the burden of fee title.	Requires land management and maintenance by the public owner.

References

1. Mack, Ruth, "Evaluation of and Recommendations for Legal, Institutional and Financial Methods for Implementing Purposes and Plans for Flood Plain Management in the Connecticut River Basin", Institute of Public Administration, New York, March 1976, (NTIS PB-253 122).

2. U.S. Army Engineers, "Charles River, Massachusetts, Main Report and Attachments", New England Division, Waltham, Mass., May 1972.

3. Bauer Engineering, "Living with a River in Suburbia", A Report to the Forest Preserve District of DuPage County, Chicago, Illinois, 1976.

CHAPTER 13

FLOOD INSURANCE

Description

Flood insurance is unique among all other measures considered in this study in that it does not directly reduce flood damage to either existing or future development, but rather indemnifies a policy holder for financial losses suffered during a flood. A clear distinction is being drawn here between flood insurance as it is available to individual property owners, much as fire insurance is available, and the National Flood Insurance Program. The latter is a multiple purpose program which contributes in many ways to reducing damage potential in our nation's flood plains. The objectives and regulations of this program are described fully in the authorizing legislation (1, 2, 3) and in subsequent regulations (4). In the context of this Chapter, flood insurance is viewed as a measure which an individual property owner may use to "solve" a flood problem. It may be the preferred alternative — preferred over temporary closures, raising in-place, relocation, or any other measure. As such it should be considered in plan formulation and evaluation.

Physical Feasibility

Flood insurance is available to all persons in communities designated by the Federal Insurance Administration as participating communities in accordance with the rules and regulations of the Program. Persons in communities not in the program are not eligible for insurance. As of March 1977, there were 15,413 communities out of a possible 20,000, participating in the program. Of those participating, 14,459 were in the Emergency Program, 954 in the Regular Program. This represented a total of 905,313 policies in force.

Insurance is available for both structure and contents. Damageable residential property not covered by insurance includes,

- Fences, retaining walls, seawalls, outdoor swimming pools, bulkheads, wharves, piers, bridges, docks; other open structures located on or partially over water; or personal property in the open.
- Land values; lawns, trees shrubs or plants, growing crops, or livestock; underground structures or underground equipment, and those portions of walks, driveways and other paved surfaces outside the foundation walls of the structure.
- Accounts, bills, currency, deeds, evidences of debt, money, securities, bullion, manuscripts or other valuable papers or records, numismatic or philatelic property.
- Animals, birds, fish, aircraft, motor vehicles (other than motorized equipment pertaining to the service of the premises and not licensed for highway use), trailers on wheels, watercraft including their furnishings and equipment.

The exceptions noted above identify property not covered by flood insurance. Property eligible for insurance has its limits in the form of limits to the amount of coverage. These limits are not generally restrictive and most property can be adequately covered. In some situations, however, these limits may impose restrictions which limit the feasibility of insurance as a measure. As of March 1977 the average flood insurance policy was for $28,900 for a residential dwelling and $42,000 for other structures.

A deductible provision in an insurance policy specifies the amount of the loss the insurer must bear before payment is made under the policy. This amount is $200. or 2 percent of the amount of the loss applied separately to both the structural loss and content loss (4). This provision makes the cost of the policy somewhat less attractive in situations where flood damage is small, but frequent.

Costs

At the present time there are two insurance rate schedules to establish the payable premium for flood insurance (4, 5). These are the chargeable (subsidized) rate and the risk premium rate. Chargeable rates are rates established by the Federal Insurance Administration (FIA) and involve a high degree of participation by the Federal Government to encourage the purchase of flood insurance. Chargeable rates are available under the Emergency Program which at the present time is scheduled to end September 30, 1978, and for structures and contents outside the special flood hazard areas (6). Most premiums being paid today are based upon this chargeable rate. The risk premium rate is the actuarial rate available under the Regular Program.

Table 13-1 shows the chargeable annual rate for flood insurance. Table 13-2 shows the maximum coverage available at this rate. Insurance for maximum coverage of a single-family dwelling in most states would cost $122.50 annually for structure and contents. This is approximately 0.41 percent of the value of the structure. The average premium per policy in the Flood Insurance Program as of March 1977 was $75.00.

TABLE 13-1

FIA CHARGEABLE (EMERGENCY) RATE TABLE
(Rates per $100 Insurance)

	Rates	
	Structure	**Contents**
Residential	.25	.35
All Other	.40	.75

TABLE 13-2

MAXIMUM COVERAGE AT CHARGEABLE RATE

	Structure	Contents
Single-Family Dwelling		
All states and jurisdictions (except below)	$ 35,000	$ 10,000
Alaska, Hawaii, Guam, and Virgin Islands	50,000	10,000
Other Residential (except single-family)		
All states and jurisdictions (except below)	100,000	10,000
Alaska, Hawaii, Guam, and Virgin Islands	150,000	10,000
Any Other Structure	100,000	100,000

Economic Feasibility

In other Chapters of this report economic feasibility was evaluated by comparing cost with damage reduced. In the case of flood insurance damage is not reduced by taking out a policy, consequently, it is never economically feasible when evaluated in this way. Flood insurance, like fire insurance, is taken out for a variety of other reasons, most of which are associated with risk and security. By paying a small premium a property owner can be covered for a full range financial loss.

Other aspects of the Flood Insurance Program do reduce flood damage. For example, requirements of community regulation of flood plain land and elevation of structures to the 100 year flood elevation. For these requirements economic feasibility could be measured by evaluating costs and damage reduced with and without a particular action.

Advantages and Disadvantages

Table 13-3 summarizes advantages and disadvantages of flood insurance as a nonstructural measure.

TABLE 13-3

ADVANTAGES AND DISADVANTAGES OF FLOOD INSURANCE

Advantages	Disadvantages
Inexpensive to the insured at the subsidized rate.	Only available to persons in communities which are eligible to participate in the Flood Insurance Program.
Available to persons in many communities.	Indemnification is limited both in magnitude and in type of damage.
Indemnification is for any flood up to the limits of the policy.	A deductible provision for each loss makes it somewhat less attractive for low damage flooding.
	Damages are not reduced.

References

1. "National Flood Insurance Act of 1968", Title XIII of the Housing and Urban Development Act of 1968, Public Law 90-488; August 1, 1968, 42 U.S.C. 4001 et seq.
2. "Housing and Urban Development Act of 1969", Public Law 91-152, December 24, 1969, 83 Stat. 379, 397.
3. "Flood Disaster Protection Act of 1973", Public Law 93-234, December 31, 1973, 86 Stat. 979.
4. "Federal Insurance Administration, National Flood Insurance Program, Rules and Regulations", Federal Register, Tuesday, October 26, 1976, Part II, Vol. 41, No. 207.
5. "Flood Insurance Manual," National Flood Insurance Program, National Flood Insurers Association, 2-75 Edition.
6. "Housing and Community Development Act of 1977, Title VII - Flood and Riot Insurance", Public Law 95-128, October 12, 1977.

APPENDIX A

SENSITIVITY ANALYSIS OF FLOOD DAMAGE DATA

As part of this investigation into nonstructural measures it was desired to investigate the magnitude and sensitivity of flood damage to various hydrologic, hydraulic, and economic parameters, and to evaluate the effectiveness of selected nonstructural measures to reduce flood damage. The parameters investigated included the elevation-frequency relationship, frequency "skew", depth-damage relationship, value of structure contents as a percentage of the value of a structure, type structure, and location in the flood plain. The effectiveness of selected nonstructural measures was evaluated by computing the damage reduced for several levels of protection. The damage values shown in graphs and tables in this Appendix were computed using **generalized** elevation-frequency and depth-damage data. While these values are useful for screening alternative measures they should not be used in lieu of more detailed, site specific data required for survey or Phase I GDM Studies.

Elevation-Frequency Relationships

In 1970 the Federal Insurance Administration (FIA) published a series of generalized elevation-frequency curves which were derived from stage-frequency curves taken from FIA Flood Plain Information Reports and Corps of Engineer's Survey Reports gathered nationwide (1). It is estimated some 150 to 200 curves were used. While the 1970 curves do not show the actual field data, they were constructed to represent an envelope of these data. Each curve was identified by what is termed a flood hazard factor (FHF) which is the difference in elevation between the 10-year and 100-year exceedance interval event. The flood hazard factor varies from 0.5 feet to 20.0 feet in increments of 0.5 feet. Each flood hazard factor curve has associated with it several additional curves of different "skew". This "skew" is not the same as the skew associated with Log-Pearson Type III discharge-frequency analyses, rather it is developed by taking percentages of the flood hazard factor and adding or subtracting these values at the 25- and 500-year exceedance intervals from a straight line through the 10- and 100-year events. Constructing the maximum positive and negative skews (skew D and I respectively) in this manner gives an envelope of curves within which most of the field data lie.

A 1974 study by an FIA consultant used a series of elevation-frequency curves and depth-damage data (provided by the FIA) to compute flood insurance rates (4). The elevation-frequency curves were nearly the same as the median curves in the 1970 FIA report. These are shown in Figure A-1. They were extrapolated to the annual event and are the ones used in most of the analyses of this study. For purposes of identification they have been designated skew M (median) in this study. A range of flood hazard factors — 1.0 to 20.0, in increments of 1.0 foot — were analyzed, although only selected ones are reported. Some inconsistencies in expected annual damage were observed and these are discussed more fully under "Computational Accuracy" in this Appendix.

Depth-Damage Relationships

In addition to the frequency information published in 1970, the FIA also presented information on depth-percent damage relationships for different type structures, with damage being expressed as a percentage of the structure and contents value (1). These data use total

value based on replacement cost (5). Separate depth-damage functions were presented for nine locations of contents and seven type structures. This information was also developed from field data, principally depth-damage functions from Corps of Engineers field offices and categorized by structure type and location of contents. *In 1974 FIA revised downward the 1970 information* using flood insurance claims data from inception of the program through June 1973 (4). These data were based upon the original acquisition cost for value of residential contents; original acquisition cost or repair less depreciation for damage to residential contents; present replacement cost for value of residential structure and replacement or repair cost less depreciation for damage to residential structure (5). More recently the Huntington District, Corps of Engineers contracted for a detailed survey of damageable property (contents and structure) along the Ohio River (2). These data, in addition to segregating damage into structure and content categories for several type structures, also segregates data for each type structure by structure value.

A plot of these three sets of data for a one story structure, with and without basement is shown in Figures A-2 and A-3. For these Figures it was assumed the contents value is 35 percent of the structure value, thus they represent total damage to contents **and** structure. The Figures show considerable variation. For purposes of this investigation it was decided to use the 1970 FIA data as the basis for the analyses, but to modify these data slightly at and below the first floor to reflect the detailed distribution of damage shown in the Huntington data. The principal reason for using the 1970 data is that they were expected to yield higher expected annual damage than the 1974 data, thus providing an upper bound on total damage and damage reduced. Table A-1 shows the 1970 modified depth-damage data used in the analysis. Four type structures and four location of contents were analyzed. These were,

1SNB One story, no basement. All contents on first floor. (Curves 01 and 27 in Reference 1)

2SNB Two or more stories, no basement. All contents on first two floors (Curves 03 and 29 in Reference 1)

1SWB One story with basement. All contents on first floor and basement (Curves 13 and 46 in Reference 1)

2SWB Two or more stories with basement. All contents on first two floors and basement. (Curves 18 and 51 in Reference 1)

Since the ratio of contents value to structure value varies with value of structure it was desired to test the sensitivity of total damage to these ratios. To do this it was assumed the ratio of value of contents to value of structure (VC/VS) was .20, .35, .50, and .65. The computed percent

TABLE A-1

1970 FIA DEPTH-DAMAGE DATA MODIFIED[1,2,3]

Damage in Percentage of Structure Value

	1SNB		2SNB		1SWB		2SWB	
Depth (feet)	**Str**	**Con**	**Str**	**Con**	**Str**	**Con**	**Str**	**Con**
-8.0					0.	0.	0.	0.
-1.0	0.		0.					
0.0	4.	0.	2.	0.	6.	8.	5.	5.
0.1	8.	5.	4.	5.	10.	21.	7.	10.
1.0	22.	35.	10.	16.	24.	40.	14.	22.
2.0	30.	50.	16.	28.	31.	58.	21.	34.
3.0	35.	60.	20.	37.	37.	70.	26.	43.
4.0	39.	68.	24.	43.	41.	76.	30.	48.
5.0	41.	74.	27.	47.	44.	80.	33.	51.
6.0	44.	78.	30.	49.	46.	82.	35.	52.
7.0	46.	81.	32.	50.	48.	83.	38.	53.
8.0	48.	83.	34.	51.	49.	85.	40.	56.
9.0	50.	85.	39.	55.	50.		44.	59.
10.0			42.	58.			46.	64.
11.0			45.	65.			47.	71.
12.0			47.	72.			48.	76.
13.0			49.	78.			49.	78.
14.0			50.	79.			50.	79.
15.0				80.				80.
				81.				81.

[1] Data are modified slightly below 0.1 ft. from those in Reference 1, to approximate the percent damage distribution indicated by the Huntington District data.

[2] These are the data used in most analyses in this study.

[3] Damage values use total value based on replacement cost (5).

TABLE A-1

1974 FIA DEPTH-DAMAGE DATA[1]

	Damage in Percentage of Structure Value							
	1SNB		2SNB		1SWB		2SWB	
Depth (feet)	**Str**	**Con**	**Str**	**Con**	**Str**	**Con**	**Str**	**Con**
-4.0						0.		0.
-3.0					0.	5.	0.	5.
-2.0					4.	7.	3.	6.
-1.0	0.		0.		8.	8.	5.	9.
0.0	7.	10.	5.	7.	11.	15.	7.	11.
1.0	10.	17.	9.	9.	18.	20.	11.	17.
2.0	14.	23.	13.	17.	20.	22.	17.	22.
3.0	26.	29.	18.	22.	23.	28.	22.	28.
4.0	28.	35.	20.	28.	28.	33.	28.	33.
5.0	29.	40.	22.	33.	33.	39.	33.	39.
6.0	41.	45.	24.	39.	38.	44.	35.	44.
7.0	43.	50.	26.	44.	44.	50.	38.	49.
8.0	44.	55.	31.	50.	49.	55.	40.	55.
9.0	45.	60.	36.	55.	51.	60.	44.	61.
10.0	46.		38.	58.	53.		46.	64.
11.0	47.		40.	65.	55.		48.	71.
12.0	48.		42.	72.	57.		50.	76.
13.0	49.		44.	78.	59.		52.	78.
14.0	50.		46.	79.	60.		54.	79.
15.0			47.	80.			56.	80.
16.0			48.	81.			58.	81.
17.0			49.				59.	
18.0			50.				60.	

[1] The 1974 data were based on the following criteria:
Value of Residential Contents - The value of the residential contents was based on original acquisition cost (no depreciation claimed).
Damage to Residential Contents - The flood damage to contents was based on original acquisition cost or repair less depreciation.
Value of Residential Structure - The value of residential structure was based on present replacement cost of structure.
Damage to Residential Structure - The flood damage to residential structure was based on replacement or repair cost less depreciation. Reference 5.

contents damage value was multiplied by each of these ratios and added to the appropriate percent damage to structure value to obtain a combined value which represented the total percent damage (contents and structure) as a percent of the structure value. For example, an expected annual damage value of 2.0 means that total damage to structure **and** contents is expected to be 2 percent of the structure value or $400 per year for a $20,000 structure.

Management Adjustments

Five types of management adjustments were analyzed,

(1) Raising a structure 3 feet and 5 feet.

(2) Protecting a structure to 3 feet and 5 feet above the first floor.

(3) Removing structure and contents from the flood plain.

Damage reduced for each adjustment was computed by subtracting from the total damage the damage remaining with the structure either raised or protected. Raising a structure was intended to simulate the potential damage reduction when an existing or new structure without basement is raised. Protecting a structure was intended to simulate conditions when openings are closed to prevent water from entering or when a structure is protected by a wall or levee.

No damage was assumed to occur to either superstructure or basement until the protection level was exceeded, then damage was assumed to be that indicated by the depth-damage functions.

Method of Analysis

The parameters and respective variables used in the analysis are summarized in Table A-2. The method of computation for expected annual flood damage is illustrated in Figure A-4. To simulate different locations of a structure in a flood plain the elevation to which different exceedance frequency events would rise was set at the first floor of a structure. The 2 yr, 5 yr, 10 yr, 15 yr, 20 yr, 25 yr, 30 yr, 50 yr and 100 yr events were each in turn assumed to be at the first floor elevation. For each event located at the first floor a series of frequency curves were used to compute expected damage. This series included three frequency curves for each FHF from 1.0 to 20.0 in increments of 1.0. One curve for each skew D, I and M. On the depth-damage side expected annual damage was computed using depth-damage relationships for each type structure and each location of contents. These were then combined using four ratios of value of contents to value of structure. The sensitivity of three sets of depth-damage data were analyzed — 1970 FIA Data, 1974 FIA Data, and Huntington District Data. One Set — the 1970 FIA Data — were used to evaluate economic feasibility. Five flood plain management adjustments were analyzed for each parameter and variable described above. These included raising the first floor elevation 3 feet and 5 feet, protecting the structure to 3 feet and 5 feet above the first floor, and removing structure and contents from the flood plain. Computations for the analyses were performed using the Hydrologic Engineering Center's computer program "Expected Annual Flood Damage Computations" (3).

TABLE A-2

HYDROLOGIC, HYDRAULIC, ECONOMIC AND MANAGEMENT PARAMETERS

Elevation-Frequency Relationship

Variables

Skew	FHF
D (Reference 1)	1.0 feet - 20.0 feet
I (Reference 1)	in increments of
M (Reference 4)	1.0 feet

Event at the First Floor

Variables

2 yr	15 yr	30 yr
5 yr	20 yr	50 yr
10 yr	25 yr	100 yr

Depth-Damage Relationship

Variables

Type Structure	Value of contents / Value of Structure	Data Source
1SNB	0.20	1970 FIA Data (Reference 1)
2SNB	0.35	1974 FIA Data (Reference 4)
1SWB	0.50	1977 Huntington District
2SWB	0.65	Data (Reference 2)

Management Adjustments

Variables

Raise Structure	Protect Structure	Remove Structure and Contents
3 ft	3 ft	
5 ft	5 ft	

Computational Accuracy

Experience in the computation of expected annual damage has shown that there are a number of factors associated with the computational technique which can affect the accuracy of the expected annual value. These include: the number and location of discrete points used to represent the elevation-frequency and depth-damage relationships; the shape of the relationships; the numerical integration method used to weight the damage values according to their probability of occurrence; the degree of asymmetry between elevation-frequency curves in a family of such curves. Often computer programs are written and used to compute expected annual damage without the realization that these factors can significantly influence the accuracy of the computation. In this study most of these factors were recognized at the beginning and steps were taken to preserve the accuracy of the computations, even so, several problems arose and several adjustments had to be made.

Most of the analyses were made using fourteen points to represent the elevation-frequency relationship (Figure A-1 data extrapolated to the annual event) and eighteen points to represent the depth-damage relationships. The maximum number of points allowed by the computer program was eighteen. These points were adequate for most computations. Some inconsistencies in computed values did, however, develop. As an example see Figure A-31 and Table A-6, where, with three feet protection and the 2 year flood event at the first floor, the damage reduced for a flood hazard factor of 12.0 feet was greater than for a flood hazard factor of 8.0 feet. Since there is virtually no damage below the first floor for a 1SNB structure, with and without the protection, it was hypothesized that the total damage, Figure A-39 and Table A-8, should increase as the flood hazard factor increased regardless of the event at the first floor and with three feet protection damage reduced should decrease since the property above the protection level is flooded more frequently as the flood hazard factor increases and the percent being protected is less. It was recognized also that the damage computed was more sensitive with the 2-year event at the first floor than with some less frequent event.

To investigate this, eighteen, instead of fourteen points, were selected to define the elevation-frequency relationship (the additional four points were taken in the more frequent range of events). This resulted in a lowering of the computed value of **total** expected annual damage of from 1.0 to 6.0 percent, and a lowering of damage reduced with three feet protection of less than 10 percent depending upon the flood hazard factor. This analysis was done for flood hazard factors from 2.0 to 14.0 and a one story, no basement structure. Next, the data were plotted and some visual smoothing was done and some of the eighteen points were modified 0.1 to 0.2 feet (elevation for a given frequency). This resulted in changes from 0.0 to 4.0 percent (from the original total values), again, depending upon the flood hazard factor. The changes in damage reduced were more than for total damage and consequently most of the inconsistencies noted above were eliminated. Similar computations were made using the smoothed data and a one story, **with basement** depth-damage relationship (2-year event at the first floor) and the difference was less than 2 percent of the original total values. Computations were also made with a less frequent event at the first floor, the 10 year event. Using the smoothed elevation-frequency data (eighteen points) for one story, with and without basement, the changes from the original total expected annual damage values using the fourteen points were negligible, less than 1.0 percent. What this analysis points to is the fact that for the 2-year event at the first floor, using four additional points (eighteen points altogether), locating the

points more judiciously, and using visual smoothing resulted in changes of up to 6.0 percent in the computed value from using only fourteen points and tolerating some slight visual bumps in the data. With the 10-year event at the first floor there were no appreciable differences in the computed values.

It was also found that inconsistencies could occur in computed values of expected annual damage because of the lack of symmetry in the family of elevation-frequency relationships used (Figure A-1 curves extrapolated to the annual event). The smoothing and using additional points, described in the second paragraph of this section, eliminated most of the inconsistencies but not all. The smoothing and additional points caused the computed values of total damage to increase from a flood hazard factor of 2.0 to 12.0 feet but decrease slightly for a flood hazard factor of 14.0 feet. It was noted by visual observation that for a flood hazard factor of 14.0 feet (Figure A-1) that the curve was slightly asymmetric near its lower end. By adjusting this curve slightly (0.8 feet at the annual event) the curve was made symmetric with the other curves. This adjustment eliminated the remaining inconsistency.

The eighteen points selected to represent the **depth-damage** relationship were selected at breaks in linearity of the function. Thus, between points, a linear relationship was assumed. These points remained the same for all analyses described in the preceeding paragraph.

The integration routine used in the analysis is especially sophisticated and was selected to overcome as many of the integration problems which are normally encountered as is possible. In addition to the data input to represent the elevation-frequency relationship the integration routine internally generates three exceedance frequency values between each pair of input values. These internally generated values help to define the nonlinearity of the elevation-frequency function. The additional points are used throughout the integration process. A detailed description of this routine may be found in Exhibit 2 of Reference 3.

The family of elevation-frequency curves shown in Figure A-1 were developed by the Federal Insurance Administration and used in the insurance rate study of Reference 4. It appears they were originally drawn with a french curve at a relatively small scale. The tabulated data in the reference appear to have been points picked-off the drawn curves. Plotted to a much larger scale these data showed some minor irregularities (bumps and dips) which caused the inconsistencies in computed values described previously. These inconsistencies were most pronounced with frequent flooding at the first floor. The maximum difference is less than 6 percent. While this percentage is not significant for the conclusions and results of this study it does cause the graphical presentations to appear inconsistent.

Sensitivity to FHF and Event at First Floor

An analysis of expected annual damage and its sensitivity to FHF and event at first floor was made for four type structures and the results are presented in Figures A-5 through A-8. The expected annual damage on the ordinate axis is total annual damage expected to occur to **structure and contents** expressed as a percentage of structure value. For example, a 10 percent value means the expected annual damage is estimated to be 10 percent of the structure value for the conditions assumed. These Figures show that the increase in expected annual damage with a larger FHF is relatively small beyond a FHF of about 8.0. That is, for a FHF greater than 8.0 the change in expected annual damage is relatively insensitive to change in FHF. This is true for all type structures and all events at the first floor especially those events greater than 5 years. For a

FHF less than 8.0 there can be considerable difference in damage depending upon the FHF and type of structure. In this range the FHF is a sensitive parameter. Figures A-5 through A-8 also show a significant variation in damage relative to the event at the first floor of the structure. This can be illustrated better by taking a cross-section through each family of curves at a given FHF. Figures A-9, A-10 and A-11 show this for FHF's of 2.0, 4.0 and 8.0. Thus, for a given flood hazard factor the curves show that there is a point (location in the flood plain beyond which expected annual damage is relatively unchanged. For an FHF = 2.0 this point is about the 15 year event, for an FHF = 4.0 it's about the 20 year, and for an FHF = 8.0 it's more nearly the 25 year event. To illustrate that this progression does not continue beyond the 25 year event, Figure A-12 shows a plot for a FHF = 20.0. When events less than 15-25 years are located at the first floor, expected annual damage increases significantly, especially below 10 years. This is true for all flood hazard factors and all type structures.

Figures A-9, A-10 and A-11 also show the difference in expected annual damage between different type structures. At the 25 year event (the relatively stable range) the difference between damage for a one story structure **with** basement and the same structure **without** were 7.0 and 1.2 percent for a FHF = 2.0; 3.1 and 2.0 for a FHf = 8.0; and 2.9 and 2.6 with a FHF = 20.0. Thus, structure type makes a large difference in expected annual damage with FHF less than 8.0, but considerably less difference when the FHF is greater than 8.0.

Before leaving this discussion on FHF and event at the first floor an explanation of the underlying interrelationship between the two may help to explain some trends in the data. Figure A-5 shows for a structure without basement that expected annual damage increases with increasing FHF for all events at the first floor. However, Figure A-7 shows, for a structure with basement, that expected annual damage increases with increasing FHF for the 2 year and 5 year event, but **decreases** with the 10 year and 25 year event. This difference is also evident in Figures A-39 and A-41 which represent total damage. Figure A-39 shows increasing damage with increasing flood hazard factor for all events at the first floor. Figure A-41 (one story with basement) shows the same trend for events less than about the 7 year, but increasing damage with **decreasing** flood hazard factors for events greater than 7 year. Why the difference? The answer lies in an understanding of how the three principal variables which determine expected annual damage interrelate. Since expected annual damage is computed by weighting each damage value by its probability of occurrence, and since more frequent events weight more than less frequent ones, the different distributions of damage and frequencies and their relative relationship cause different trends in the data. Figure A-13 illustrates how for a given event at the first floor an increase in FHF results in an increase in the frequency of the event at every elevation above the first floor. An increase in FHF results in a decrease in the frequency of event at every elevation below the first floor. These statements can be illustrated by referring to Figure A-13. It shows frequency curves for flood hazard factors of 4.0 and 8.0 located with their 25 year event at the first floor (-2.4 feet). With the 25 year event fixed relative to the first floor and because a frequency curve with a FHF = 8.0 has a greater slope than a curve with a FHF = 4.0, the exceedance interval for the larger FHF must be less above the first floor and greater below. As the event at the first floor changes, the frequency of events above and below the first floor changes. If instead of the 25 year event at the first floor it was the 2 year then there would be more frequent events occurring above the first floor. This is illustrated in Figure A-13. The reverse is also true: As the event at the first floor becomes less frequent the events above the first floor become less frequent.

Regarding damage, the relationship is much more simple. For structures with basements damage exists below the first floor while for structures without basements it does not (except for minor damage to elevation -1.0 feet). Above the first floor damage potential in a structure with basement is slightly less than for a structure without basement.

Combining these three facts the following conclusions may be drawn regarding the decrease (Figure A-7) in expected annual damage between FHF = 4.0 and 8.0 for the 10 year and 25 year events at the first floor and the increase for events 2 year and 5 year. The decrease occurs because expected annual damage below the first floor is considerably greater for the lower FHF than for the larger FHF and this offsets and exceeds the lesser expected annual damage above the first floor for the lower FHF. Figure A-14 illustrates this point. When the 2 year event is at the first floor, damage in the basement is much smaller and there is not enough difference to offset the much greater damage for the larger FHF occurring above the first floor. Single story structures with no basement have no appreciable damage below the first floor, thus the general trend of increasing damage with increasing FHF holds. Figure A-15 illustrates this point.

Sensitivity to Skew

Figures A-16 through A-19 show the sensitivity of expected annual damage to variations in the elevation-frequency curve. Skew D represents the maximum positive skew variation and skew I the maximum negative skew variation. Results of the analysis show that,

- For structures without basements (1SNB, 2SNB) there is only a small difference between expected annual damage for skew D and skew I when the event at the first floor is the 15 year or greater and the FHF is greater than 4.0.
- For structures with basements (1SWB, 2SWB) there is a significant variation (± 100%) between expected annual damage computed using skew D and skew I when the frequency relationship has a FHF less than about 10.0

Two measures of variation were investigated — the relative difference in expected annual damage, and percentage difference. The former are reported here because the relative magnitude relates more meaningfully to cost. The percentage difference was highly variable becoming as much as 125 percent.

This means that for structures without basements variations in the skew of the frequency relationship are not likely to be significant except for structures low in the flood plain and with FHF less than about 4.0. Structures with basements are most sensitive to skew except in the higher range of flood hazard factors.

Sensitivity to Structure Type

Structures with basements and structures with a second story, distribute damageable property over a greater height than do structures with only one story. One would expect differences in expected annual damage depending upon structure type. Figures A-9 thru A-11 show some of these differences. As to be expected, damage is greater in a structure with basement than without because the property in the basement is damaged by events that do not cause damage to a structure without a basement and because events which do cause damage to both type structures (events above the first floor) cause greater damage because of property in the basement. The opposite is true for two story structures. Less damageable property in the first story results in less overall damage than for single story structures. Generally, expected annual

damage for a structure without basement is 55 to 75 percent of the same structure with a basement. This can be illustrated by overlaying Figures A-5 and A-6, and Figures A-7 and A-8. The difference is quite uniform over the full range of flood hazard factors. Figure A-11 shows that for flood hazard factors equal to 8.0 the expected damage for the 1SNB and 2SWB is essentially the same. This similarity continues for flood hazard factors greater than 8.0 feet.

Sensitivity to Ratio of Contents Value to Structure Value

An analysis of total expected annual damage using four ratios of contents value to structure value (.20, .35, .50, .65) showed a consistent trend with variations in FHF, event at first floor and type structure. Only skew M data were analyzed. Generally, structure damage was 37 to 50 percent of the total damage **before** taking into account the relative value of contents to structure. For example, for a 1SNB structure the percent structure damage varied from about 46% to 37% for FHF's of 2.0 and 20.0, respectively. Also, for a given FHF the percentage is relatively insensitive to the event at the first floor. For example, for a 1SWB the percentage varies from 37% to 41% for the 2 year to 100 year event at the first floor and a FHF = 4.0. When the relative value is taken into account the percentage of the damage which is attributable to the structure ranges from 83 to 75% with a ratio of 0.20 (VC/VS) to 61 to 47% with a ratio of 0.65 (VC/VS). Within each range the percentage decreases as the FHF increases. Figure A-20 shows the variation in expected annual damage for a 1SNB with the 10 year event at the first floor. The percentage differences shown in the table are typical for all type structures and all events at the first floor.

This analysis shows that the percentage difference between ratios of value of contents to value of structure — 0.20 to 0.35, 0.35 to 0.50, 0.50 to 0.65 — generally varies from 10 to 19% over the full range of flood hazard factors and events at the first floor. Thus, expected annual damage is only moderately sensitive to reasonable variations in the ratio of contents value to structure value and more importantly this variation can be estimated. For example, if a ratio of 0.40 were assumed initially but later revised to .50 the expected annual damage could be expected to increase approximately 15 percent.

Sensitivity to Depth-Damage Data Source

Figures A-21 and A-22 show the influence of the three different depth-damage data sets discussed previously upon expected annual damage. For a single story structure without basement the difference is relatively uniform and the curves regular. Figure A-21 shows that as the event at the first floor increases and goes into the 15 to 25 year range the difference is moderate (about 1.0 percent of structure value). For the 5 year and 2 year events the difference increases to 3 and 7 percent respectively. For a single story structure with basement the functions are nonuniform and irregular for flood hazard factors less than about 8.0 feet, but become more stable as the flood hazard factor increases beyond this point. The differences between different data sets is considerably greater than for structures without basements over most flood hazard factors, but decrease as the flood hazard factor increases. The irregularity of the curves for structures with basements is caused by the differences in depth-damage functions below and above the first floor (Figure A-3). Below the first floor, for example, the Huntington data shows the greatest damage and the 1970 data considerably less. Above the first floor the Huntington data shows damage considerably less than the 1970 data. This reversal of damage functions causes the irregularities shown in Figure A-22. The 1974 FIA data varies considerably from the other and generally yields the least expected annual damage.

The principal conclusions from this analysis are that the relative differences between expected annual damage computed using different depth-damage data decreases significantly when the event at the first floor goes to 25 year and beyond, and that annual damage is particularly sensitive to the assumed distribution of damage below the first floor. Because damage occurring below the first floor is weighted with a higher frequency of occurrence than damage above the first floor, the total expected annual damage is particularly sensitive to assumptions made about the distribution of damage and the physical feasibility of damage actually occurring below the first floor.

Sensitivity to Management Adjustments

Five flood plain management adjustments were simulated and damage reduced computed. These adjustments were: raising a structure three feet and five feet; protecting a structure to three feet and five feet above the first floor; and removing both structure and contents from the flood hazard area. Damage reduced by each adjustment is presented graphically and in tabular form in the Figures and Tables which follow. Table A-3 is an index to these data.

Damage reduced data follow the same trend as total damage data with respect to location in the flood plain. The damage reduced is greatest where the 2 year event is at the first floor and the reduction decreases rather sharply from the 2 year event to the 15 year event. Beyond the 15 year event damage reduced decreases with less frequent events, however the reduction is significantly less. These trends exist for all types of adjustments. The influence of flood hazard factor varies depending upon the adjustment, type structure, and location in the flood plain.

The amount of damage reduction achieved by the different adjustments varied depending upon the type of adjustment, type of structure, flood hazard factor and event at the first floor. Removing both structure and contents from the flood plain reduced damage 100 percent. Data plotted in Figures A-39 through A-42 and tabulated in Table A-8 are the total damage for the type structure, flood hazard factor, and event at the first floor indicated. The damage reduction for raising or protecting a structure 5 feet varies from 80 to 100 percent for flood hazard factors less than or equal to 4.0 feet. This is true for all type structures and for the full range of events at the first floor. Generally, as the event at the first floor becomes less frequent the percent reduction increases. When the flood hazard factor is greater than 4.0 feet (4.0 to 20.0) the percent reduction decreases from a minimum of 80 percent to a minimum of 22 percent. A 3 foot adjustment (raising or protecting) reduces damage 59 to 100 percent for flood hazard factors less than or equal to 4.0 feet and a minimum of 11 percent for flood hazard factors greater than 4.0 feet. Once again the specific amount of reduction depends upon type structure, flood hazard factor, and location in the flood plain.

Removal of structure and contents is, of course, the most effective of the five adjustments for reducing damage. Since it was assumed that damage with the structure and contents removed is zero, the damage reduced (without — with) is equivalent to total damage (without condition). Next comes raising or protecting a structure 3 feet. Raising reduces damage the most for one and two story structures **without** basements. The reduction may be the same for low flood hazard factors, but as the flood hazard factor increases raising becomes more effective. The principal reason is that when the elevation raised is exceeded damage increases gradually, whereas, when protection is exceeded damage jumps from zero to a significant amount because immediate inundation to the protection level is assumed. Protection is the most effective

adjustment for one and two story structures **with** basements and flood hazard factors equal to or less than about 8.0 feet. With basement structures protection is assumed to eliminate all damage below the protection level, whereas with raising damage still occurs to the basement since it still exists below the elevation raised. At flood hazard factors of approximately 8.0 feet protection becomes less effective than raising because the damage caused by immediate inundation begins to outweigh the protection of basement property. In other words, the reason protection reduced damage more than raising is because of the reduction to basement damage, yet as the flood hazard factor increases this reduction is offset by the increased damage caused by immediate inundation which does not occur when a structure is raised.

TABLE A-3

INDEX TO FIGURES AND TABLES WHICH SHOW DAMAGE REDUCED BY SELECTED MANAGEMENT ADJUSTMENTS

Management Adjustment	Figures (1970 FIA Data)	Tables (1970 FIA Data)	Tables (1974 FIA Data)
Raising Structure 3 feet	23 through 26	A-4	A-9
Raising Structure 5 feet	27 through 30	A-5	A-10
Protecting Structure 3 feet	31 through 34	A-6	A-11
Protecting Structure 5 feet	35 through 38	A-7	A-12
Removing Structure and Contents from Flood Hazard Area	39 through 42	A-8	A-13

References

1. U.S. Department of Housing and Urban Development, "Flood Hazard Factors, Depth-Damage Curves, Elevation-Frequency Curves, Standard Rate Tables" Federal Insurance Administration, September 1970.

2. U.S. Army Engineers, "Technical Report on Representative Flood Damage to Residential Properties", Huntington District, Unpublished Report, 1977.

3. U.S. Army Engineers, "Expected Annual Flood Damage Computation: Users Manual", Computer Program 761-X6-L7580, The Hydrologic Engineering Center, June 1977.

4. MacFadyen, D. J., "Flood Insurance Rate Calculation Computer Program", Unpublished report prepared for the Federal Insurance Administration, 3 April 1974. (Sections 7.1 and 7.2 contain the depth-damage data used to compute flood insurance rates).

5. U.S. Army Engineers, "Study of Relationships of Flood Depth vs Flood Damage to Contents in Residential and Commercial Categories", Civil Works - Planning Division, Project Analysis Task Group, Technical Paper No. 2, 1974.

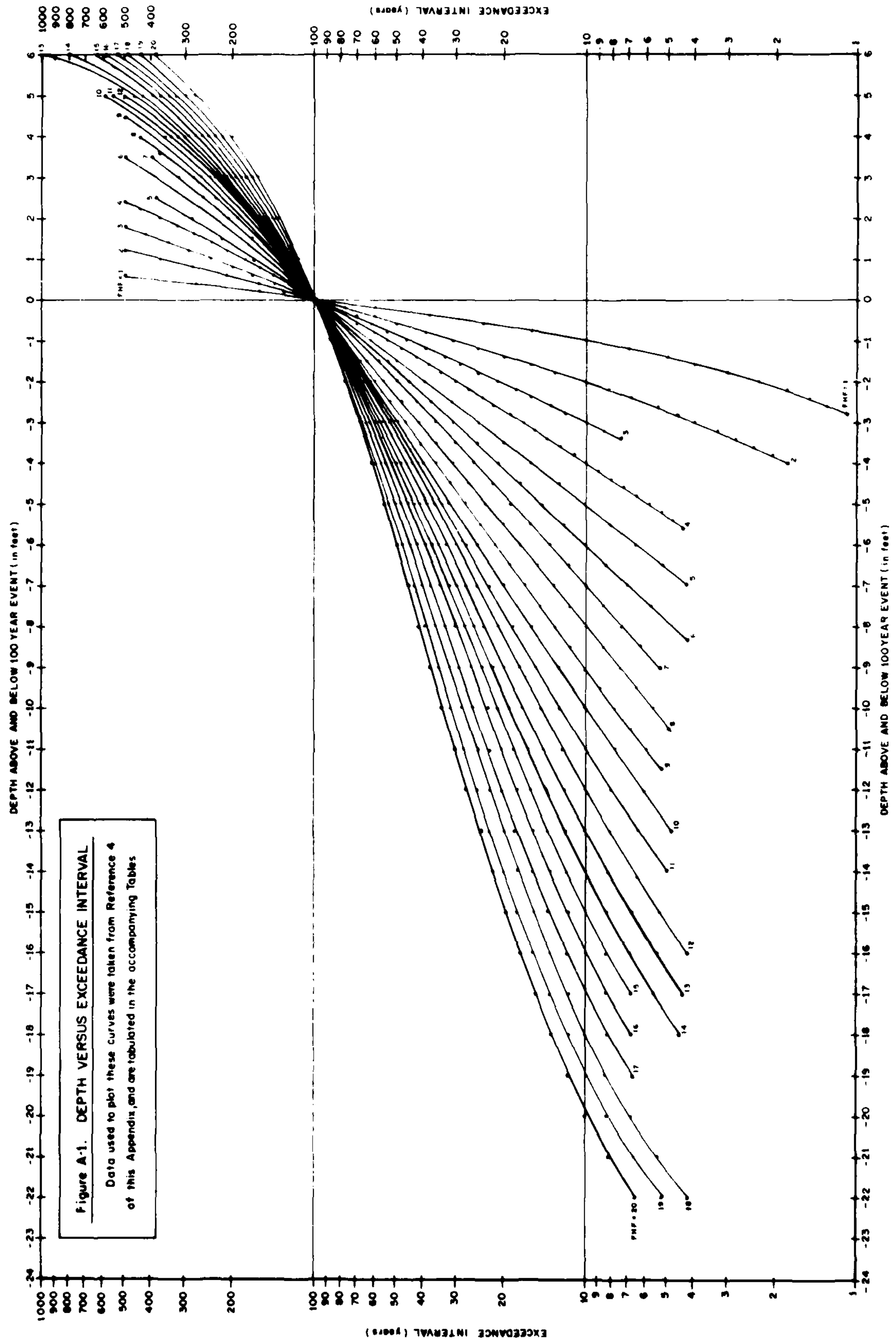


Figure A-1. DEPTH VERSUS EXCEEDANCE INTERVAL

Data used to plot these curves were taken from Reference 4 of this Appendix, and are tabulated in the accompanying Tables

FIGURE A-1

DEPTH-EXCEEDANCE INTERVAL DATA[1]

Depth Above and Below 100 year Event (feet)	Flood Hazard Factor (feet) 1.0	2.0	3.0	4.0
+2.4				500
+2.2				440
+2.0				370
+1.8			500	320
+1.6			420	280
+1.4			350	240
+1.2		500	290	210
+1.0		370	240	180
+ .8		280	200	160
+ .6	500	210	170	142
+ .4	275	160	140	125
+ .2	160	130	120	110
0.0	100	100	100	100
– .2	60	78	82	88
– .4	38	60	70	80
– .6	24	50	62	70
– .8	16	39	54	60
–1.0	10	31	46	54
–1.2	7	25	39	48
–1.4	5	20	33	42
–1.6	4	16	29	38
–1.8	3	13	25	34
–2.0	2.3	10	21	30
–2.2	1.8	8.2	18	27
–2.4	1.5	6.8	16	24
–2.6	1.3	5.4	13.5	22
–2.8	1.1	4.6	12.0	19
–3.0		4.0	10.0	17
–3.2		3.3	8.6	15.5
–3.4		2.8	7.4	14.0
–3.6		2.4	6.4	12.5
–3.8		2.1	5.6	11.0
–4.0		1.8	5.0	10.0
–4.2			4.4	9.0
–4.4			3.9	8.0
–4.6			3.5	7.2
–4.8			3.1	6.5
–5.0			2.7	5.8
–5.2				5.2
–5.4				4.8
–5.6				4.4

[1] From Reference 4 this Appendix.

FIGURE A-1 (Continued)

DEPTH-EXCEEDANCE INTERVAL DATA[1]

Depth Above and Below 100 year Event (feet)	Flood Hazard Factor (feet)				
	5.0	6.0	7.0	8.0	9.0
+4.5					500
+4.0				440	400
+3.5		500	400	350	320
+3.0		380	320	280	265
+2.5	380	300	260	230	220
+2.0	285	235	210	190	185
+1.5	220	190	170	160	155
+1.0	168	150	140	138	134
+0.5	130	122	115	112	115
0.0	100	100	100	100	100
− .5	80	82	82	87.5	88.1
−1.0	62	66	70	75.0	77.1
−1.5	50	54	58	65.0	68.0
−2.0	39	45	50	56.0	59.5
−2.5	31	37	42	48.0	52.5
−3.0	25	31	36	42.0	46.0
−3.5	20	25	30	36.0	40.6
−4.0	16	21	26	31.0	35.8
−4.5	12.5	17.5	22	27.0	31.8
−5.0	10.0	14.5	19	23.4	27.9
−5.5	8.2	12.0	16	20.0	24.5
−6.0	6.6	10.0	13.5	17.5	21.7
−6.5	5.2	8.4	11.5	15.0	19.0
−7.0	4.3	7.0	10.0	13.0	16.9
−7.5		5.8	8.6	11.5	14.9
−8.0		4.2	7.4	10.0	13.0
−8.5			6.3	8.7	11.5
−9.0			5.4	7.5	10.0
−9.5				6.5	8.9
−10.0				5.6	7.8
−10.5				4.9	6.8
−11.0					6.0
−11.5					5.2

[1] From Reference 4 this Appendix.

FIGURE A-1 (Continued)

DEPTH-EXCEEDANCE INTERVAL DATA[1]

Depth Above and Below 100 year Event (feet)	Flood Hazard Factor (feet)				
	10.0	11.0	12.0	13.0	14.0
+6.0				999	800
+5.0	590	550	500	460	430
+4.0	350	340	320	300	290
+3.0	240	235	220	215	210
+2.0	172	170	163	161	160
+1.0	130	129	128	127	126
0.0	100	100	100	100	100
−1.0	79.5	80.0	80.5	81	82
−2.0	63.0	63.5	65.0	67	68
−3.0	50.1	51.0	53.0	56	57
−4.0	40.0	41.5	43.9	46.5	48
−5.0	32.0	33.8	36.0	39.0	41
−6.0	25.4	27.5	30.0	32.9	35
−7.0	20.0	22.5	25.0	27.7	30
−8.0	16.0	18.5	21.0	23.5	25.8
−9.0	12.6	15.2	17.5	20.0	22.0
−10.0	10.0	12.5	14.6	17.0	19.0
−11.0	7.8	10.0	12.1	14.3	16.4
−12.0	6.2	8.0	10.0	12.0	14.0
−13.0	4.8	6.4	8.1	10.0	11.9
−14.0		5.0	6.6	8.2	10.0
−15.0			5.3	6.7	8.3
−16.0			4.2	5.4	6.9
−17.0				4.4	5.6
−18.0					4.5

[1] From Reference 4 this Appendix.

FIGURE A-1 (Continued)

DEPTH-EXCEEDANCE INTERVAL DATA[1]

Depth Above and Below 100 year Event (feet)	Flood Hazard Factor (feet)					
	15.0	**16.0**	**17.0**	**18.0**	**19.0**	**20.0**
+6.0	630	582	534	486	438	390
+5.0	400	375	350	325	300	275
+4.0	275	261	247	233	219	205
+3.0	202	194	186	186	170	162
+2.0	155	151	147	143	139	135
+1.0	125	123	121	119	117	115
0.0	100	100	100	100	100	100
-1.0	83	84	85	86	87	88
-2.0	69.6	70.5	73	74.0	76	77.5
-3.0	58.0	60.2	63	64.5	66.5	68.5
-4.0	50.0	52.0	54.5	56.5	59.0	61.5
-5.0	42.9	45.0	48.0	50.0	53.0	55.5
-6.0	37.0	39.4	42.0	44.5	47.3	50.0
-7.0	32.0	34.5	37.3	39.9	42.9	45.5
-8.0	28.0	30.3	33.0	35.8	38.6	41.9
-9.0	24.1	26.5	29.5	32.0	35.0	37.5
-10.0	21.0	22.9	26.0	28.8	31.8	34.0
-11.0	18.4	20.4	22.7	24.9	28.3	30.4
-12.0	16.0	17.9	20.4	22.8	24.9	27.9
-13.0	13.8	15.4	18.1	19.9	22.7	24.1
-14.0	11.8	13.4	15.7	17.8	20.0	22.0
-15.0	10.0	11.4	13.7	15.4	17.8	19.6
-16.0	8.4	10.0	11.7	13.5	15.4	17.5
-17.0	6.8	8.4	10.0	11.5	13.6	15.2
-18.0		6.8	8.3	10.0	11.4	13.3
-19.0			6.7	8.4	10.0	11.5
-20.0				6.8	8.3	10.0
-21.0				5.4	6.6	8.2
-22.0				4.2	5.2	6.5

[1] From Reference 4 this Appendix.

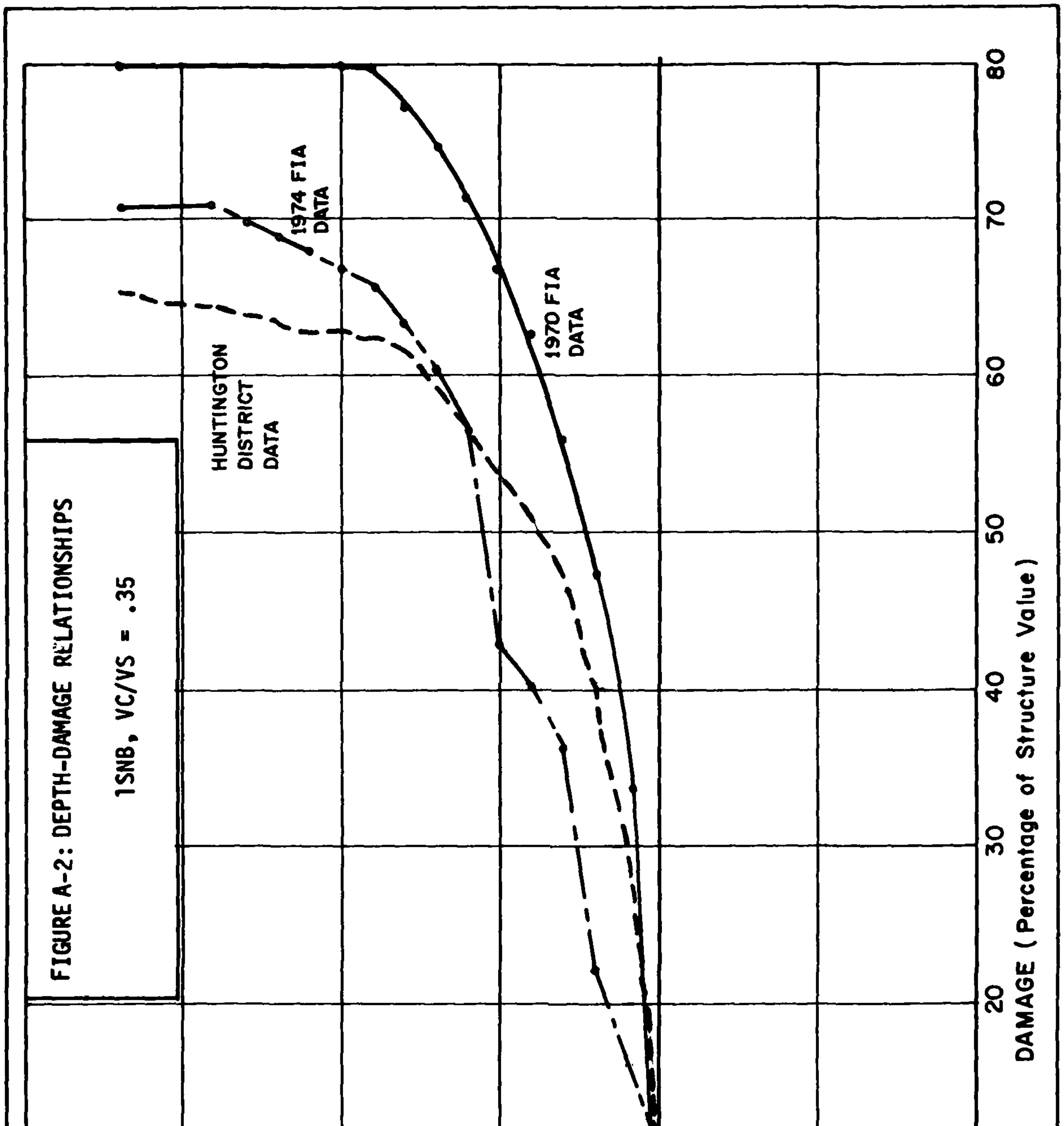


FIGURE A-2: DEPTH-DAMAGE RELATIONSHIPS

1SNB, VC/VS = .35

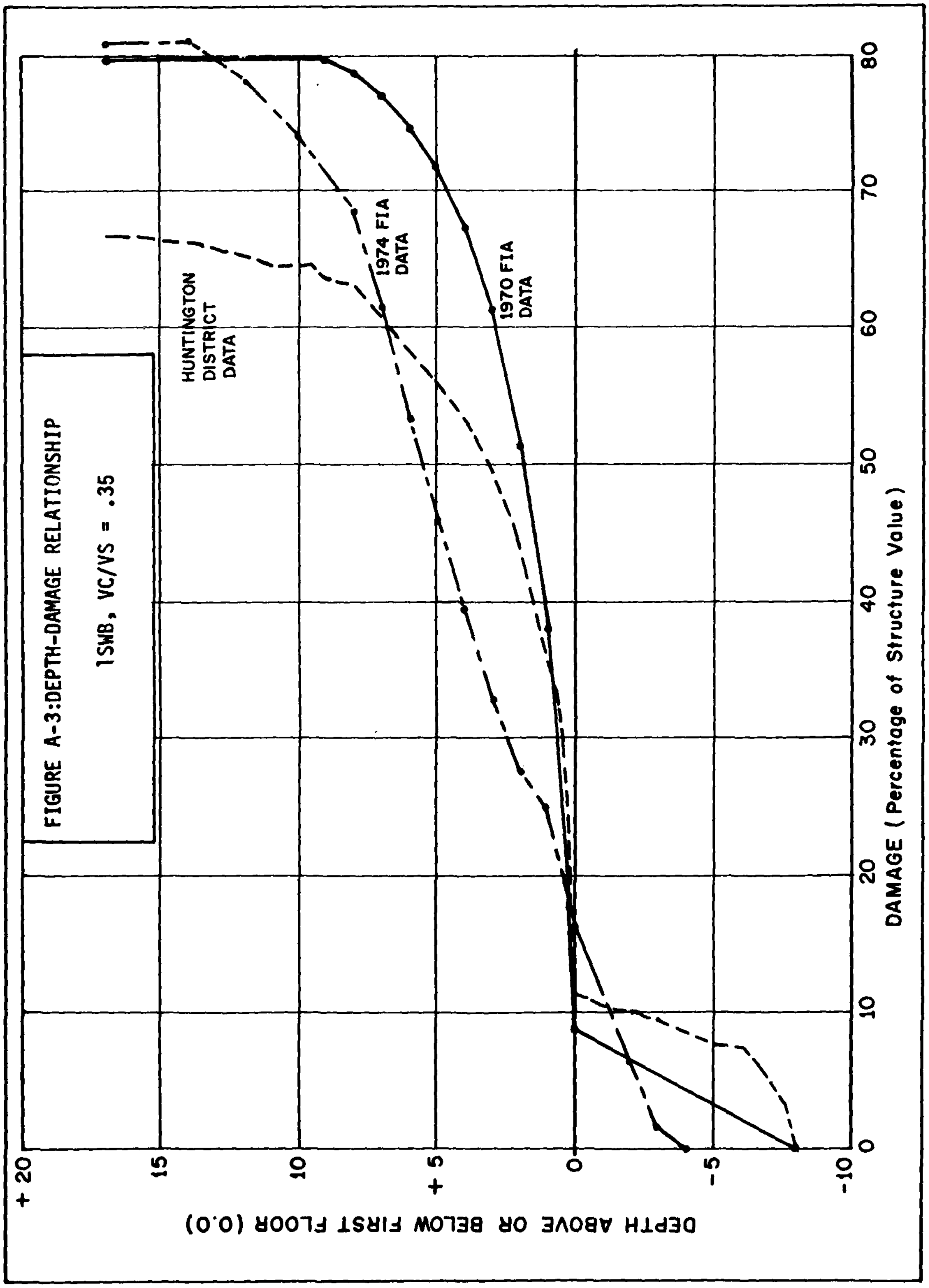


FIGURE A-3: DEPTH-DAMAGE RELATIONSHIP

1SWB, VC/VS = .35

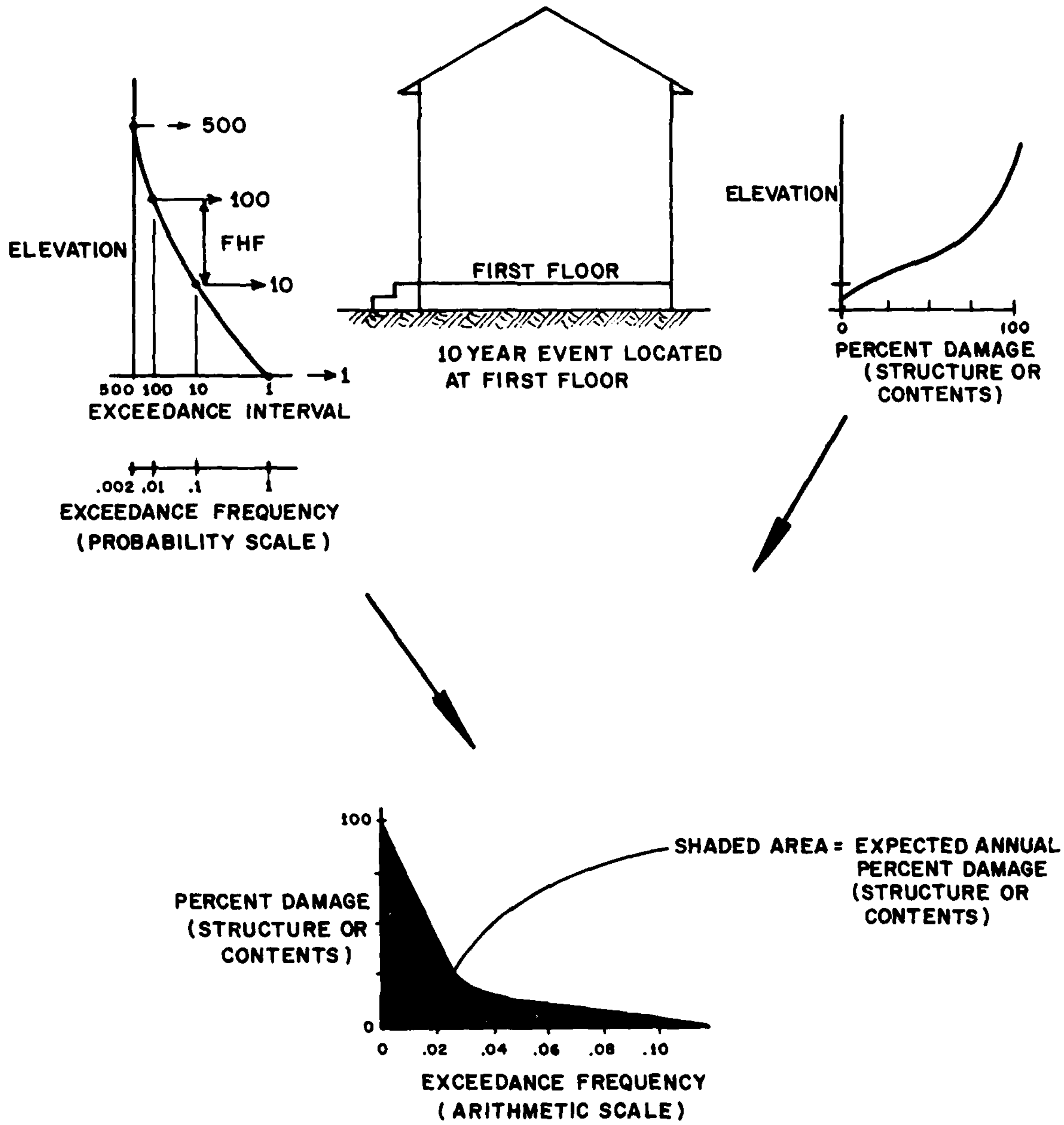


Figure A-4. EXPECTED ANNUAL FLOOD DAMAGE COMPUTATION

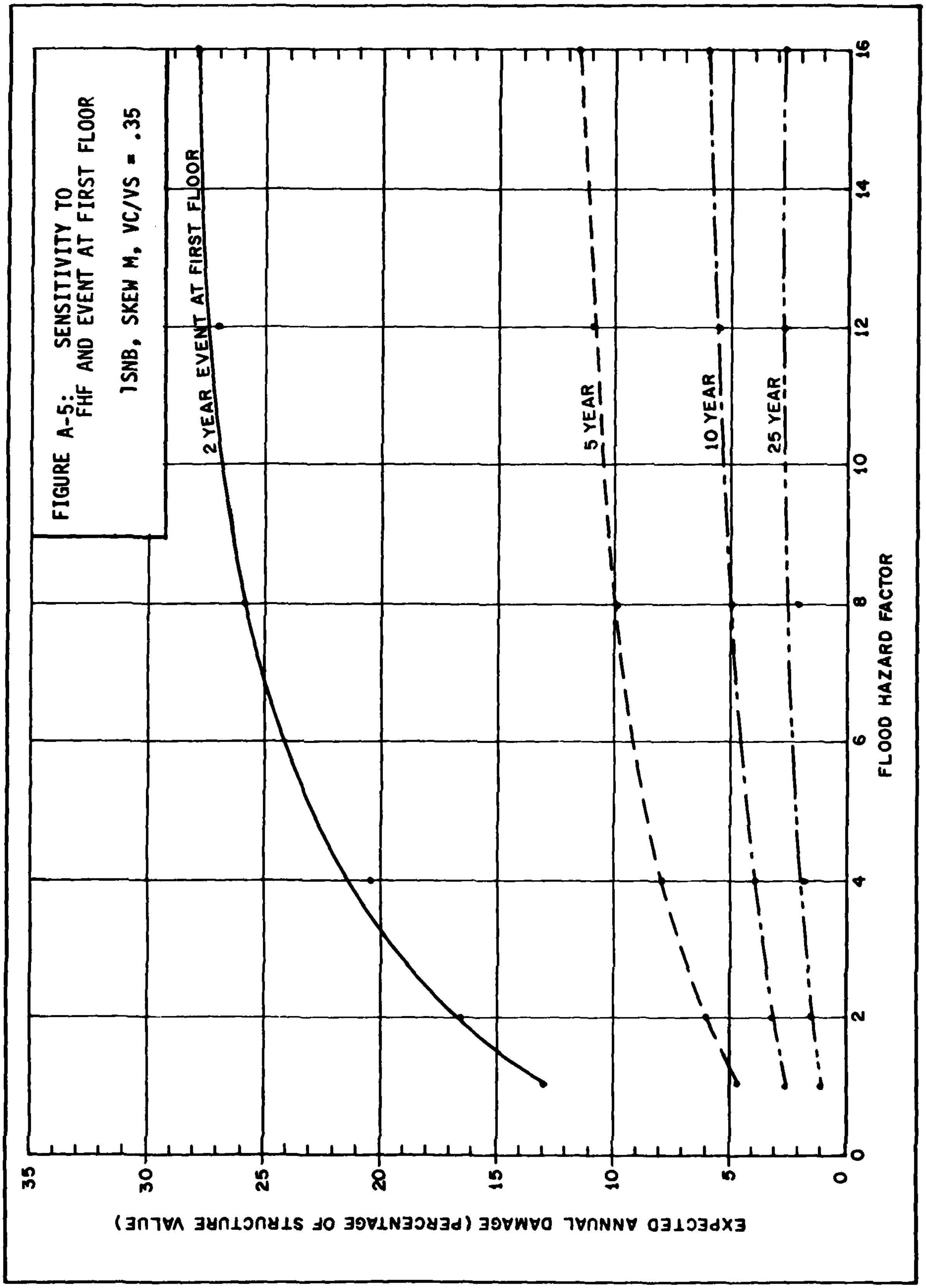


FIGURE A-5: SENSITIVITY TO FHF AND EVENT AT FIRST FLOOR

1SNB, SKEW M, VC/VS = .35

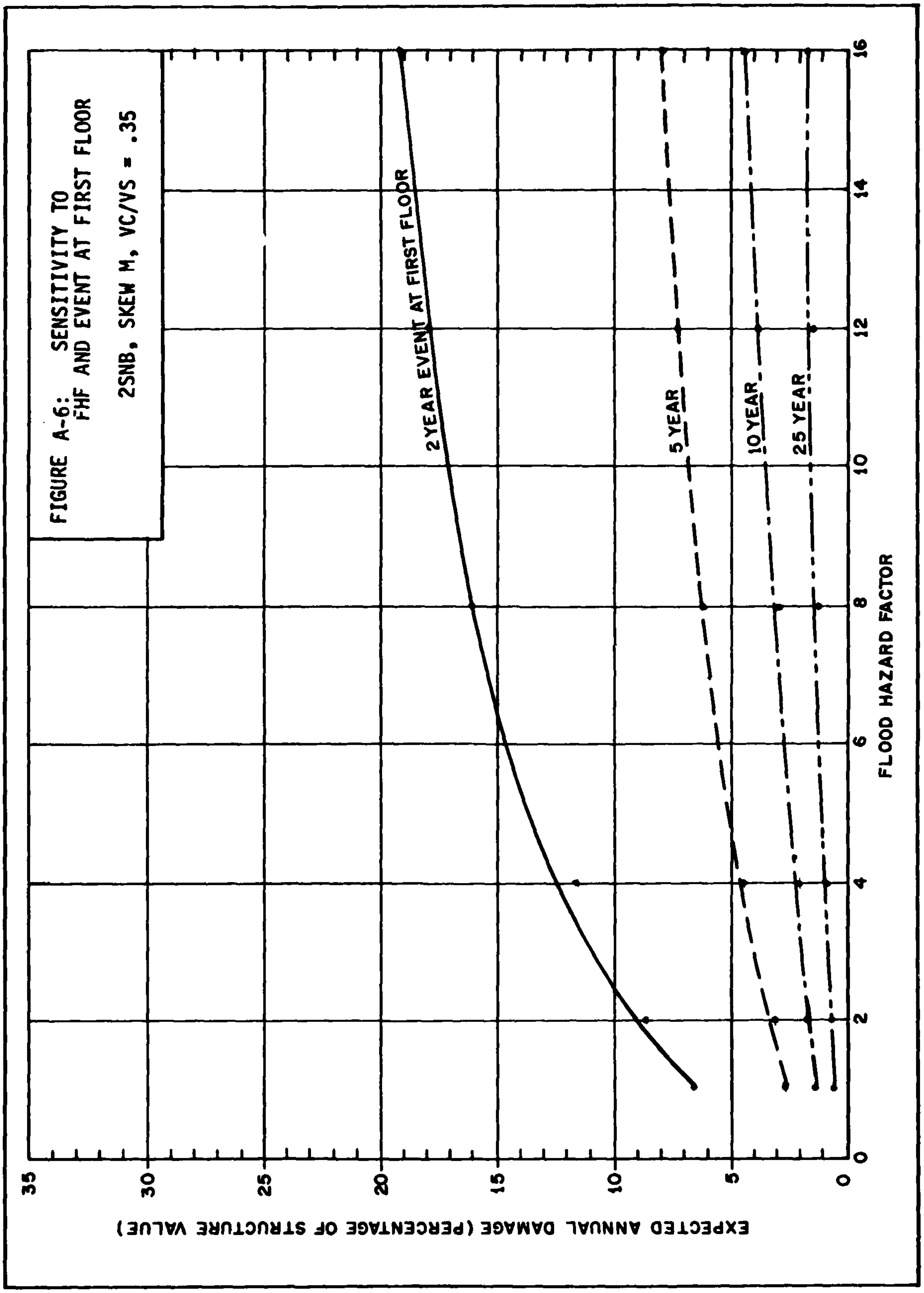


FIGURE A-6: SENSITIVITY TO FHF AND EVENT AT FIRST FLOOR

2SNB, SKEW M, VC/VS = .35

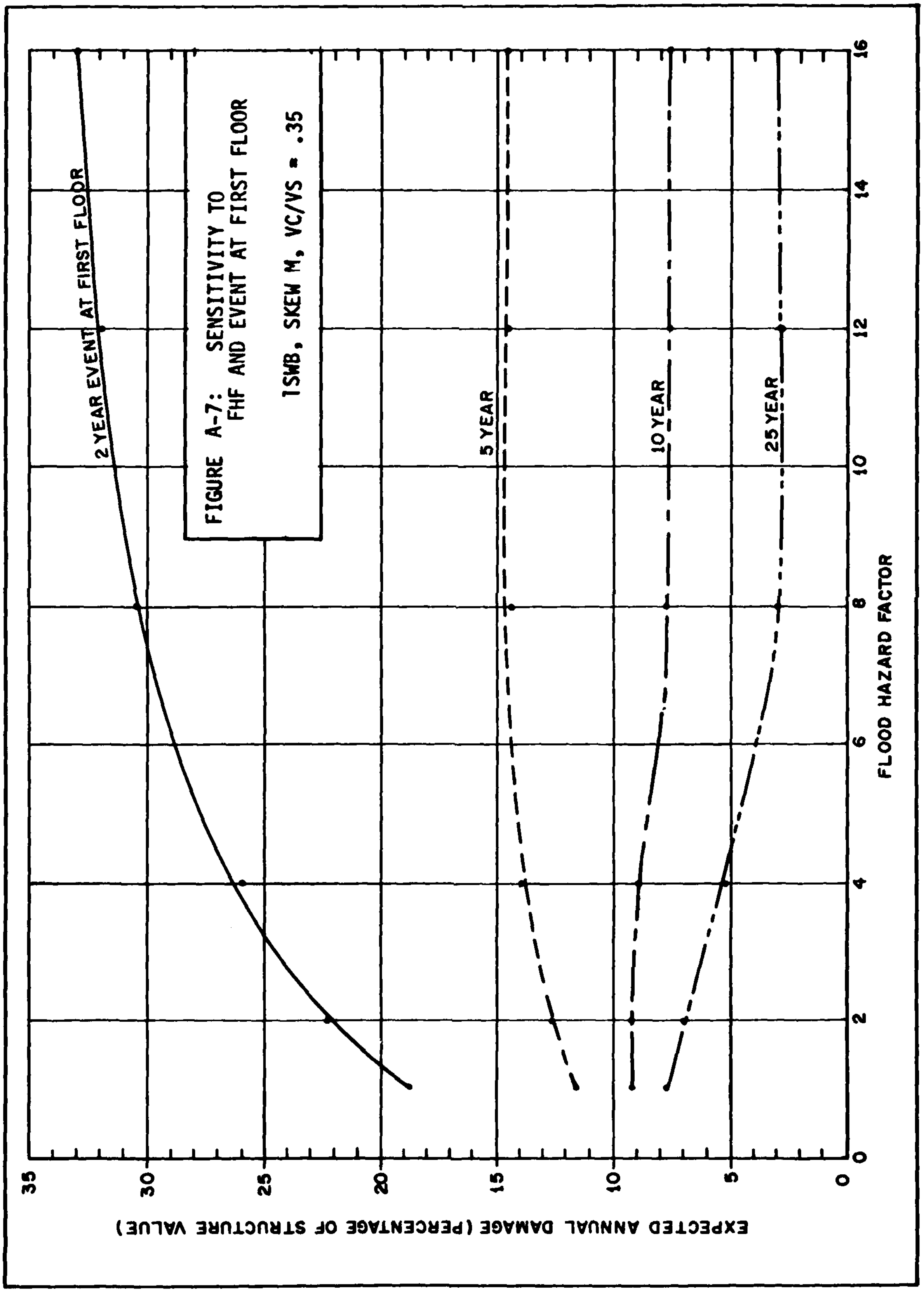


FIGURE A-7: SENSITIVITY TO FHF AND EVENT AT FIRST FLOOR

TSWB, SKEW M, VC/VS = .35

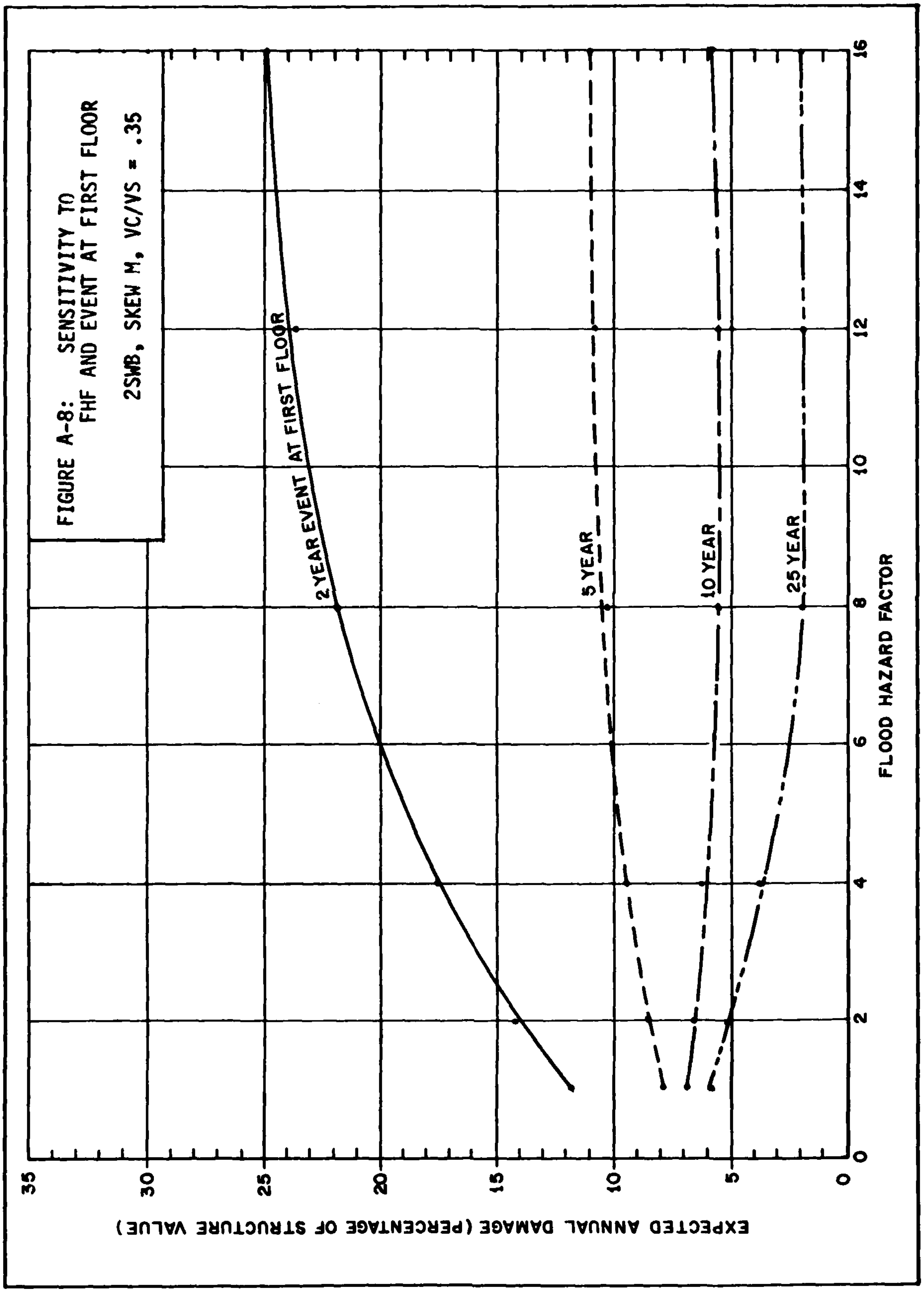


FIGURE A-8: SENSITIVITY TO FHF AND EVENT AT FIRST FLOOR

2SWB, SKEW M, VC/VS = .35

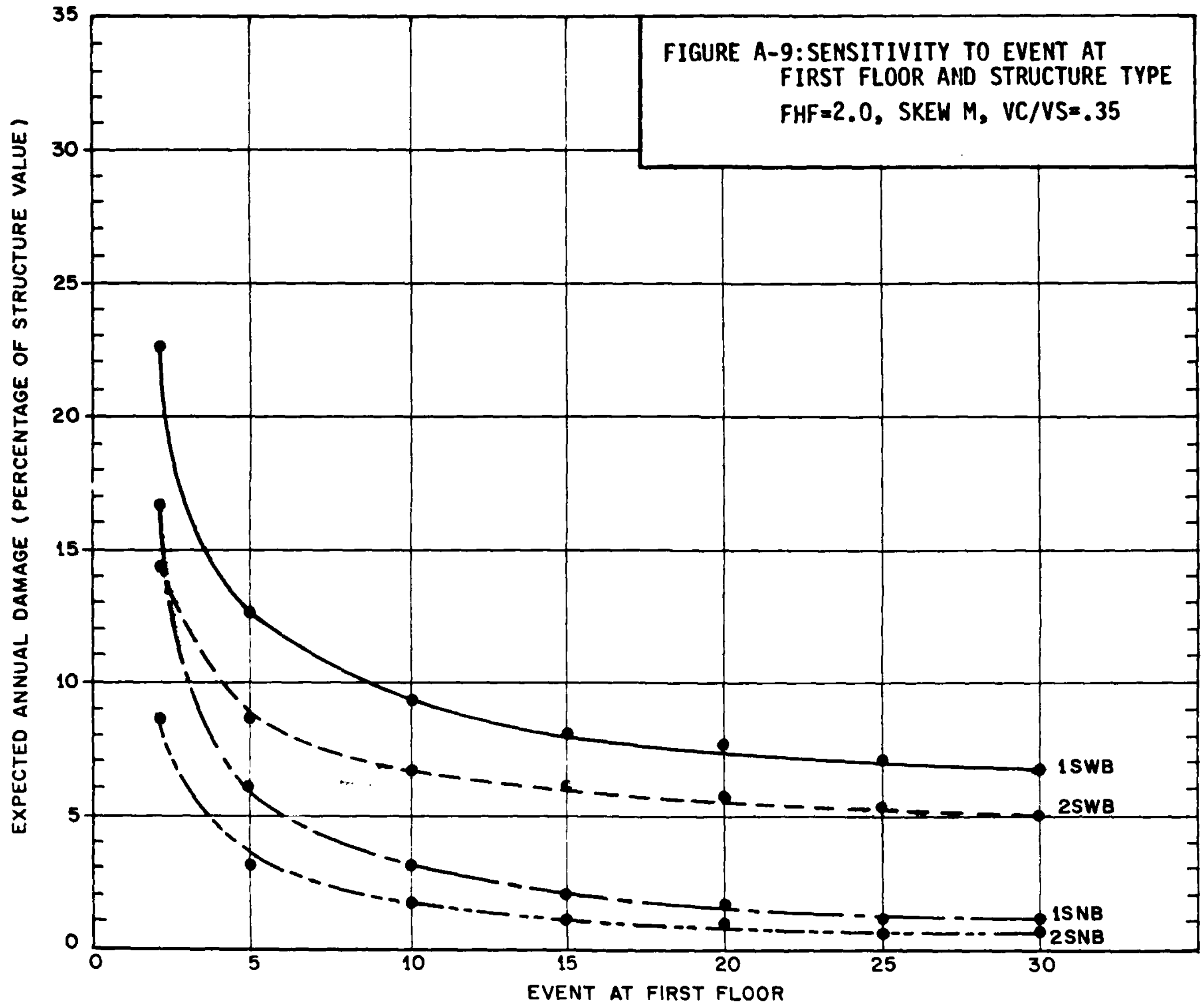


FIGURE A-9: SENSITIVITY TO EVENT AT FIRST FLOOR AND STRUCTURE TYPE
FHF=2.0, SKEW M, VC/VS=.35

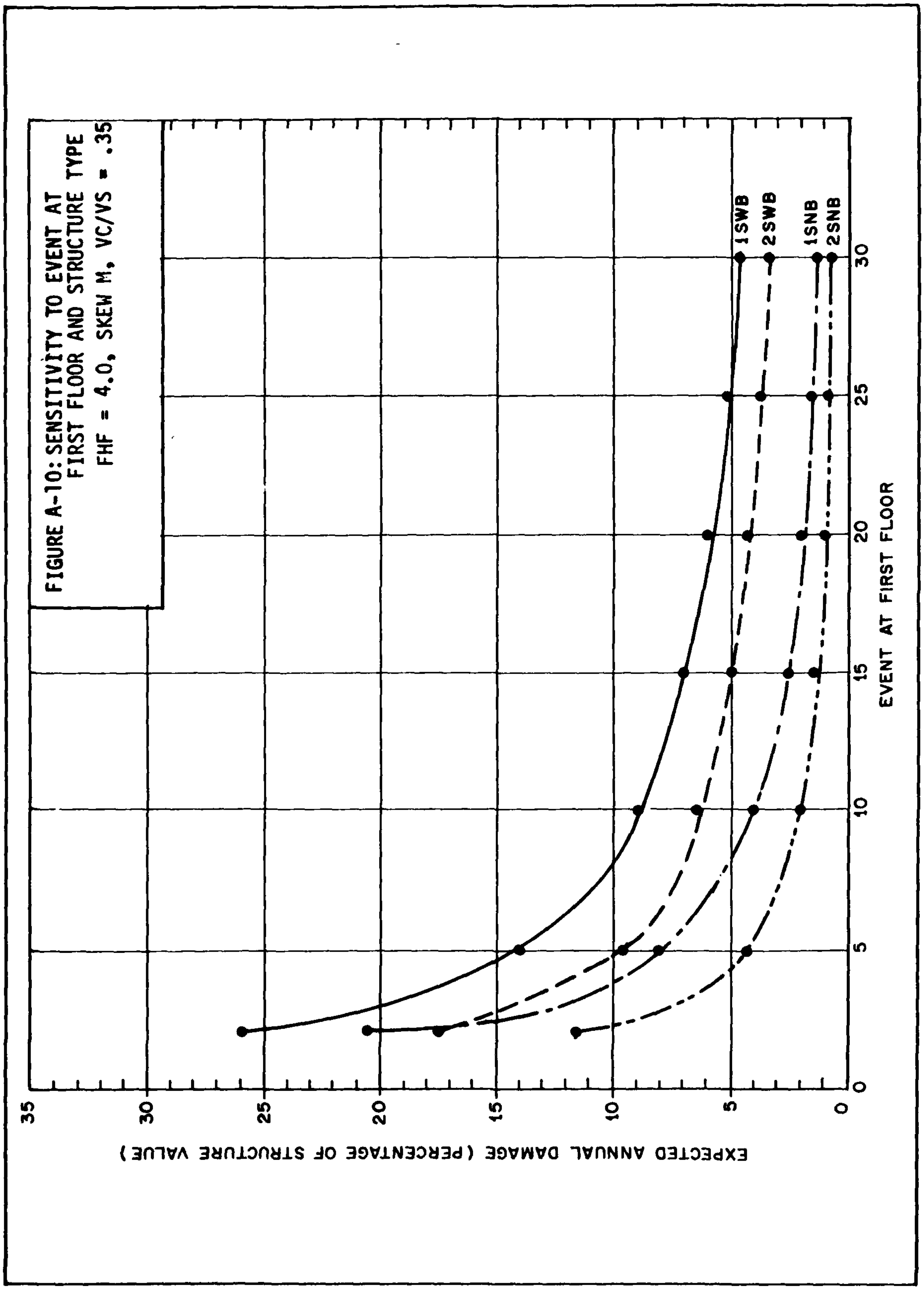


FIGURE A-10: SENSITIVITY TO EVENT AT FIRST FLOOR AND STRUCTURE TYPE
FHF = 4.0, SKEW M, VC/VS = .35

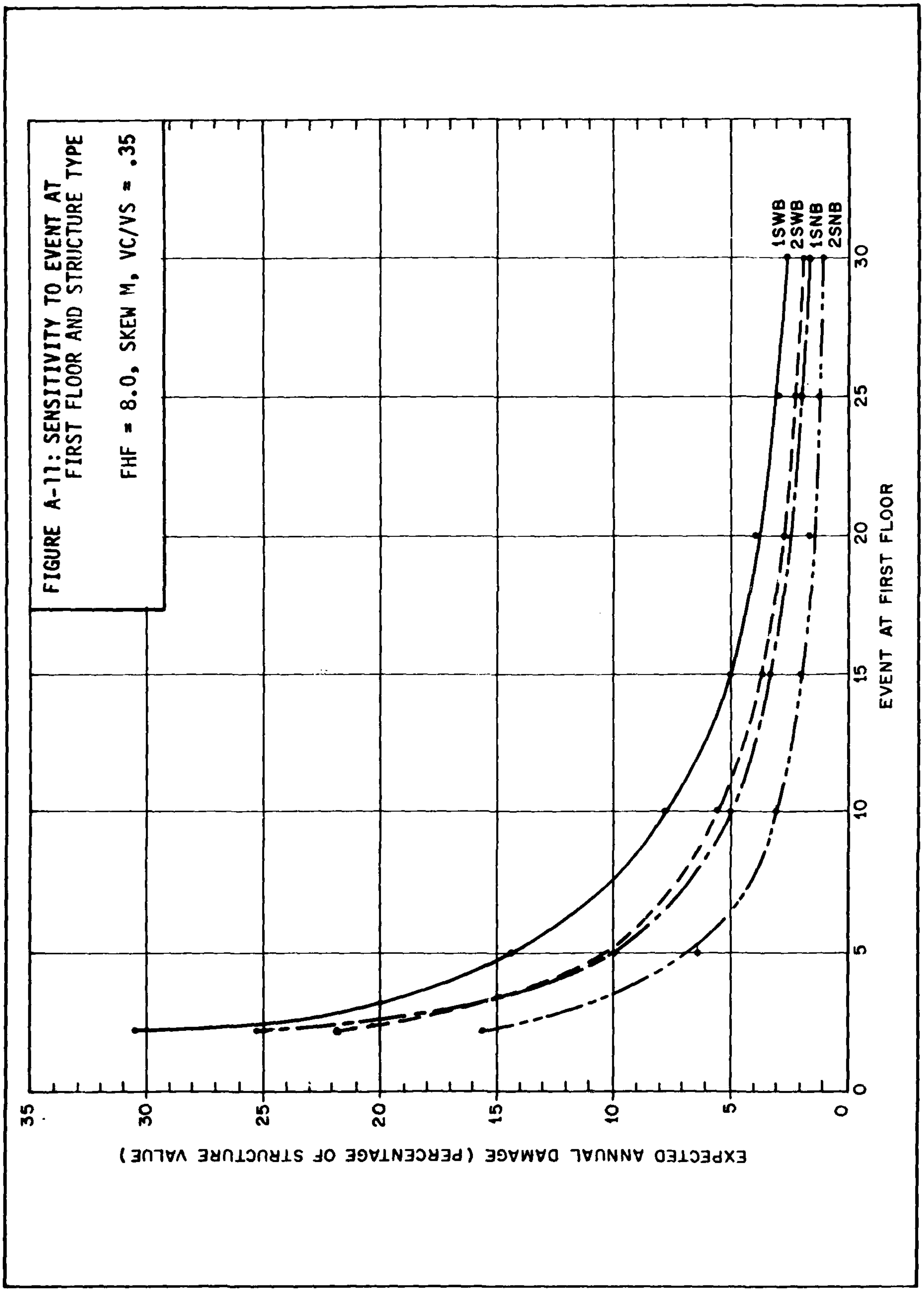


FIGURE A-11: SENSITIVITY TO EVENT AT FIRST FLOOR AND STRUCTURE TYPE

FHF = 8.0, SKEW M, VC/VS = .35

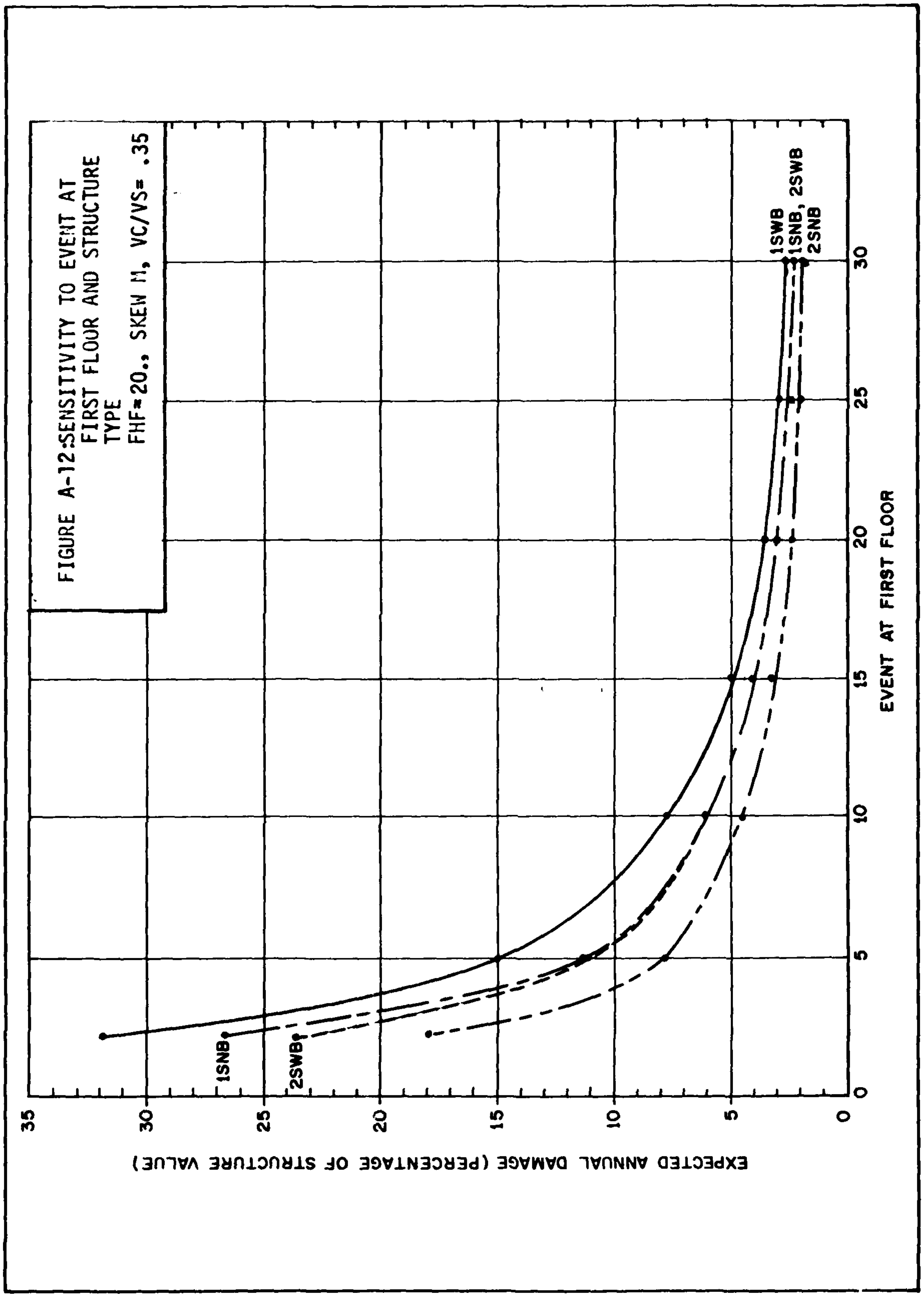


FIGURE A-12: SENSITIVITY TO EVENT AT FIRST FLOOR AND STRUCTURE TYPE
FHF=20., SKEW M, VC/VS= .35

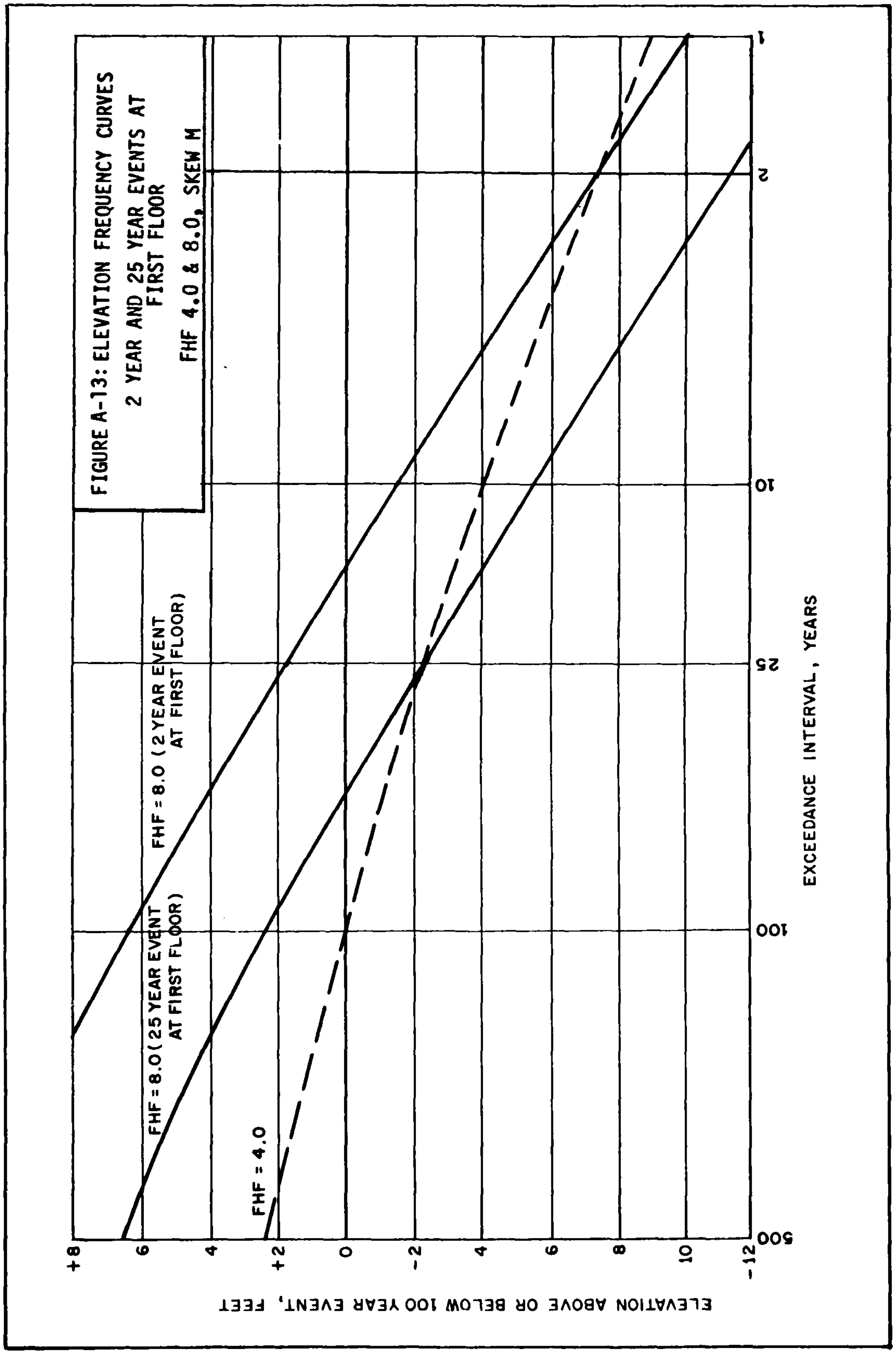
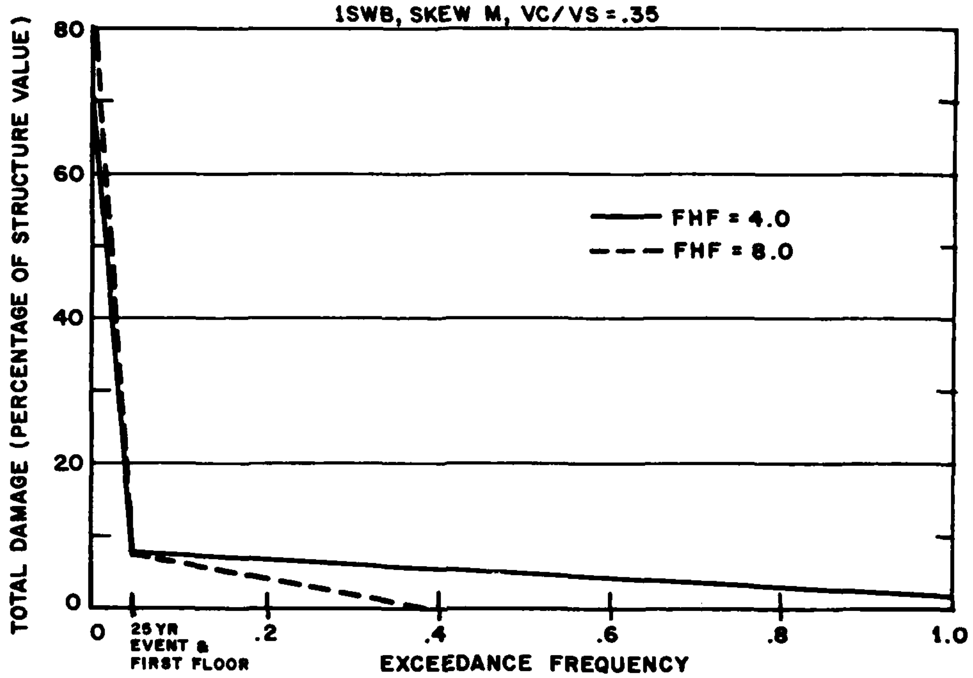


FIGURE A-13: ELEVATION FREQUENCY CURVES
2 YEAR AND 25 YEAR EVENTS AT
FIRST FLOOR
FHF 4.0 & 8.0, SKEW M

Figure A-14: DAMAGE-FREQUENCY RELATIONSHIP

25 YEAR EVENT AT FIRST FLOOR



2 YEAR EVENT AT FIRST FLOOR

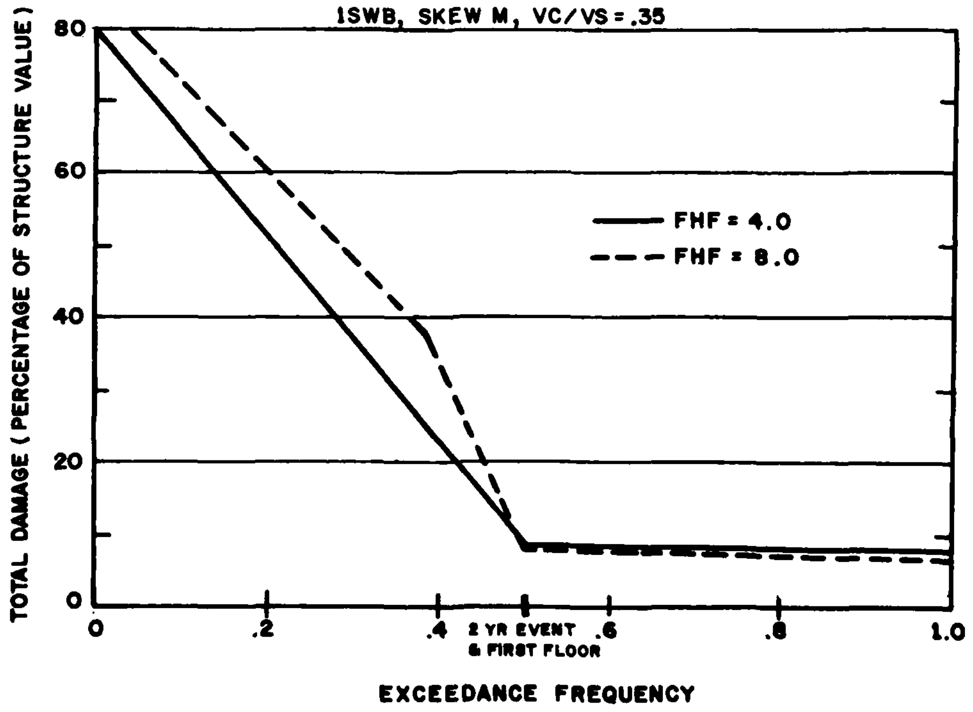
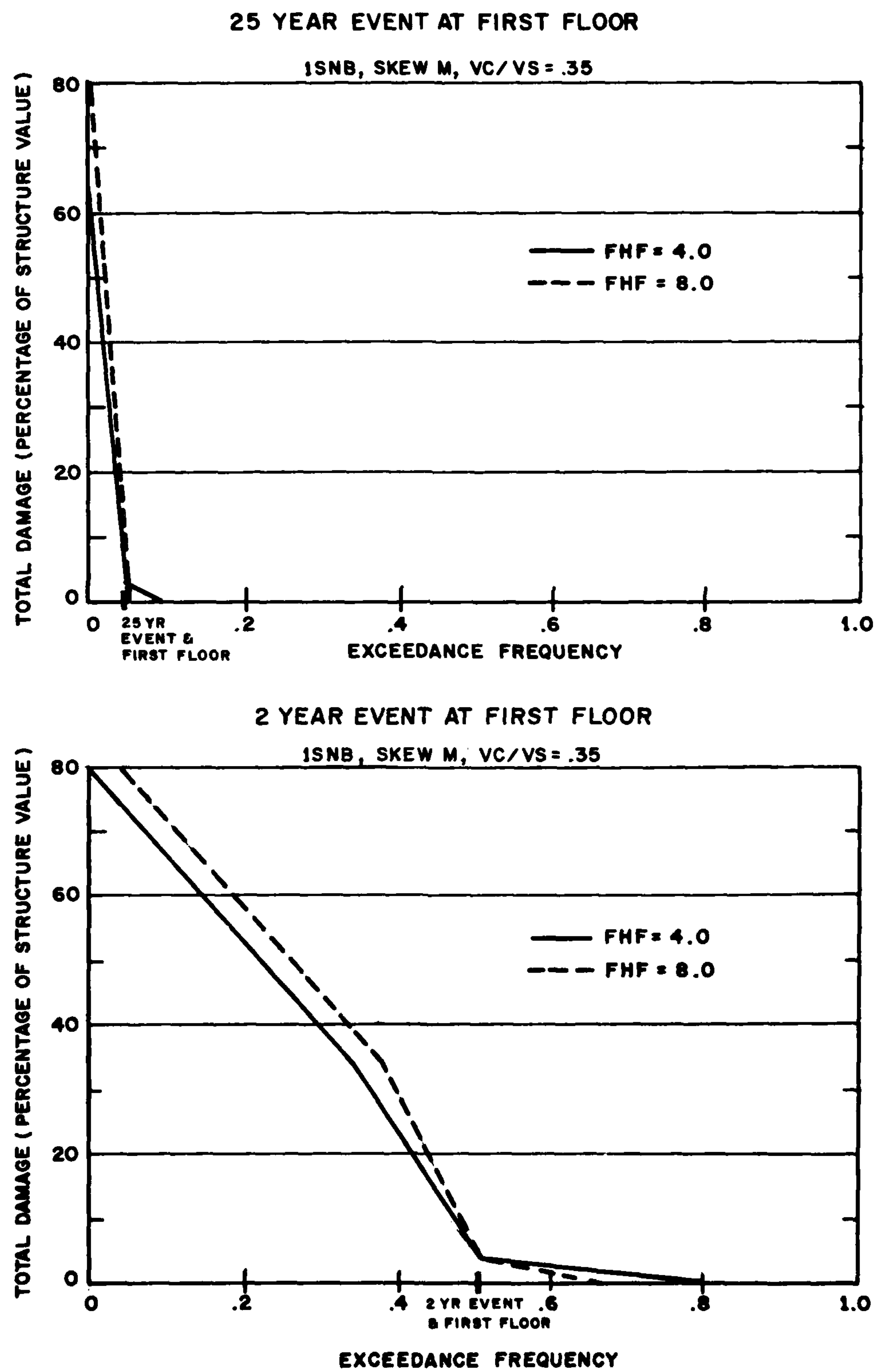


Figure A-15: DAMAGE-FREQUENCY RELATIONSHIP



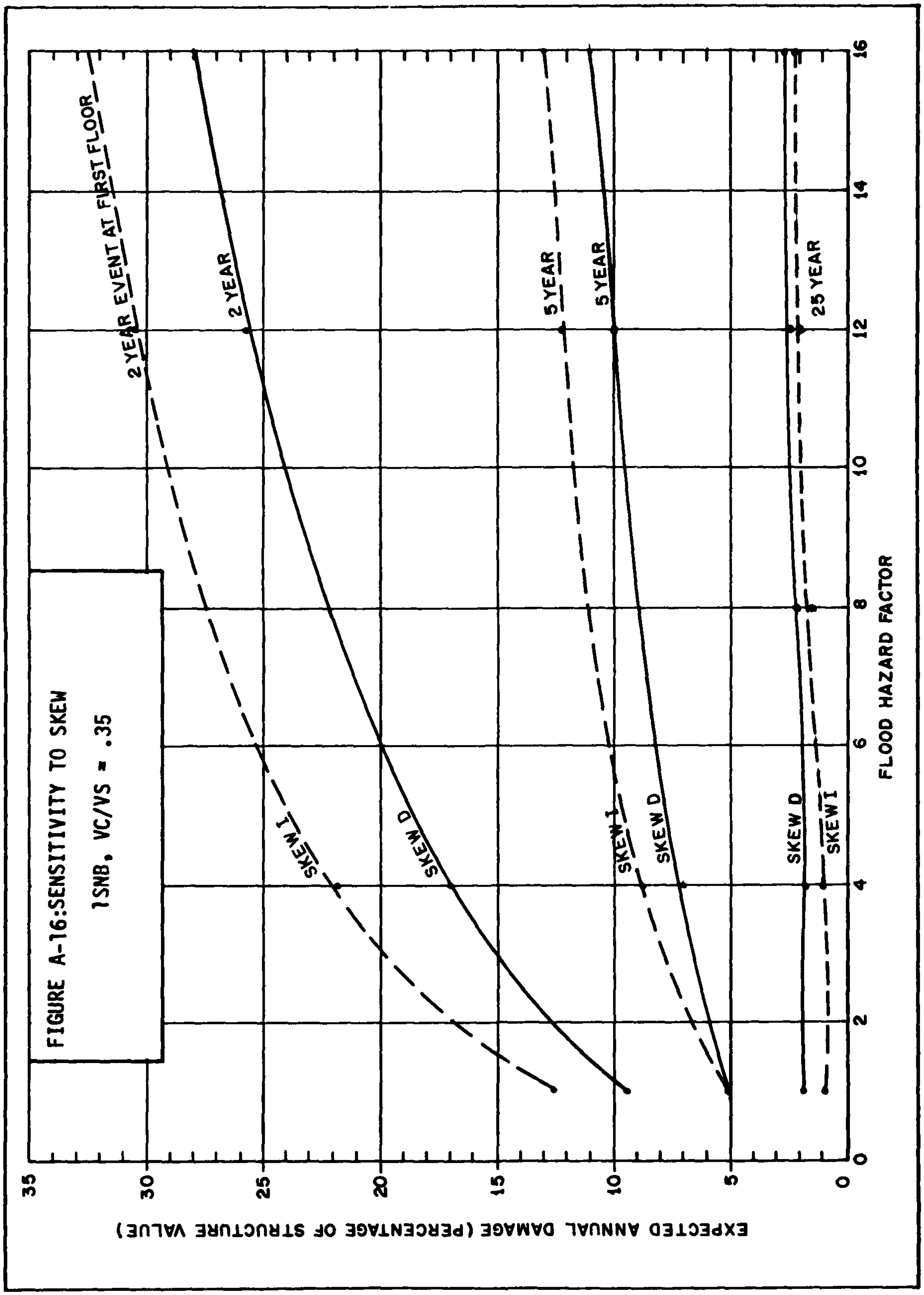


FIGURE A-16:SENSITIVITY TO SKEW
1SNB, VC/VS = .35
2 YEAR EVENT AT FIRST FLOOR
2 YEAR
2 YEAR
5 YEAR
5 YEAR
25 YEAR
SKEW I
SKEW D
SKEW I
SKEW D
SKEW D
SKEW I
0
5
10
15
20
25
30
35
0
2
4
6
8
10
12
14
16
EXPECTED ANNUAL DAMAGE (PERCENTAGE OF STRUCTURE VALUE)
FLOOD HAZARD FACTOR

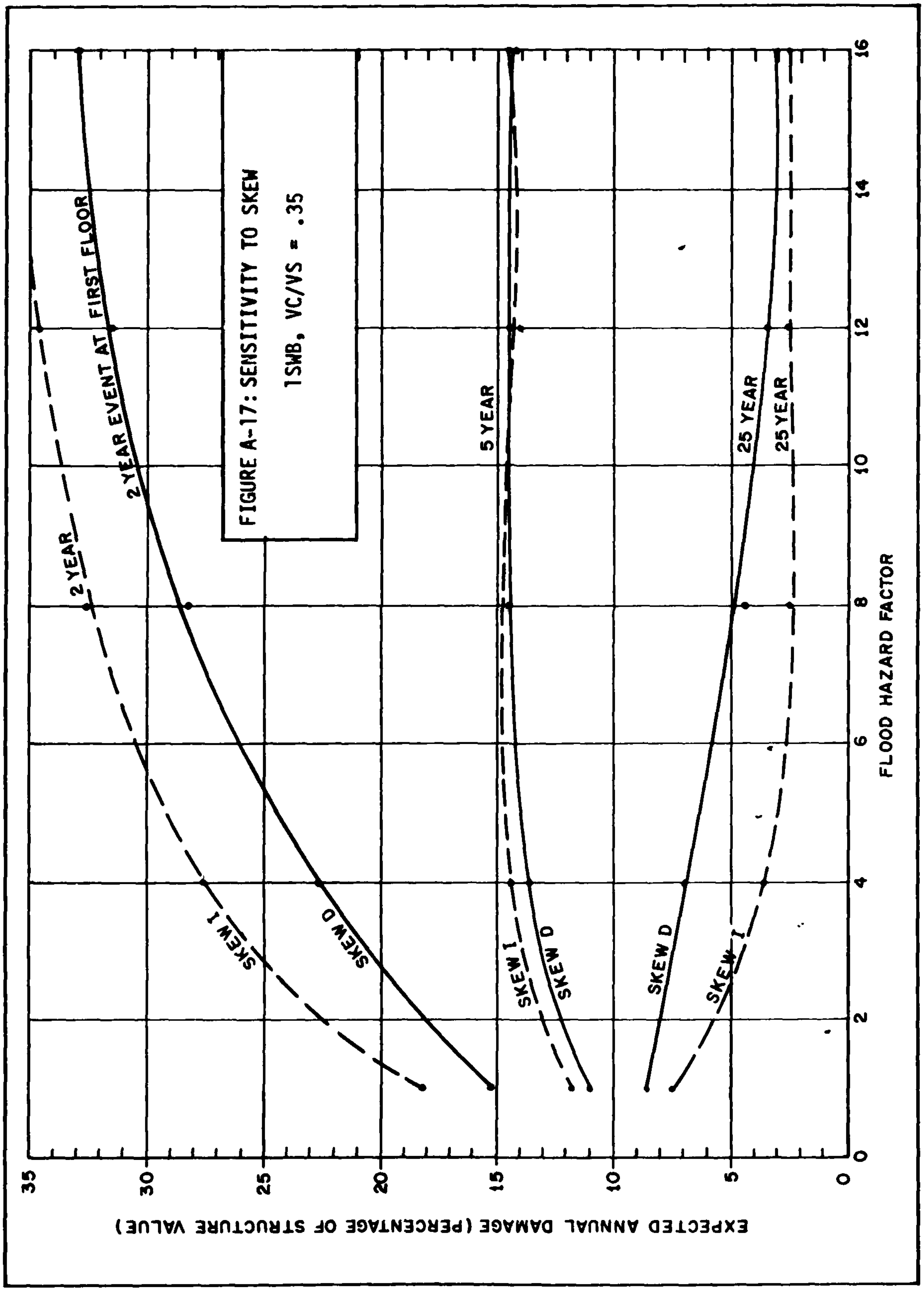


FIGURE A-17: SENSITIVITY TO SKEW

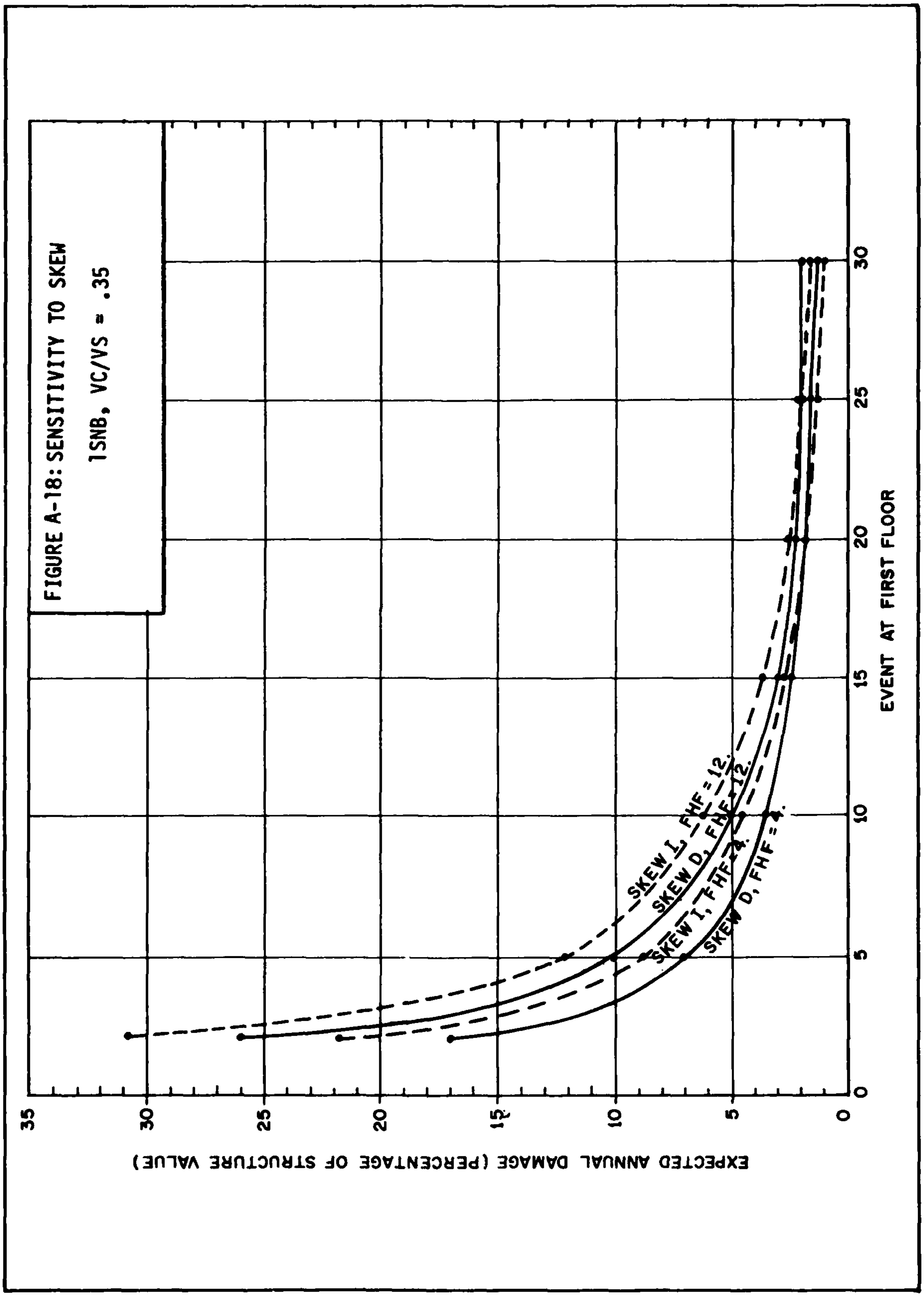


FIGURE A-18: SENSITIVITY TO SKEW

1SNB, VC/VS = .35

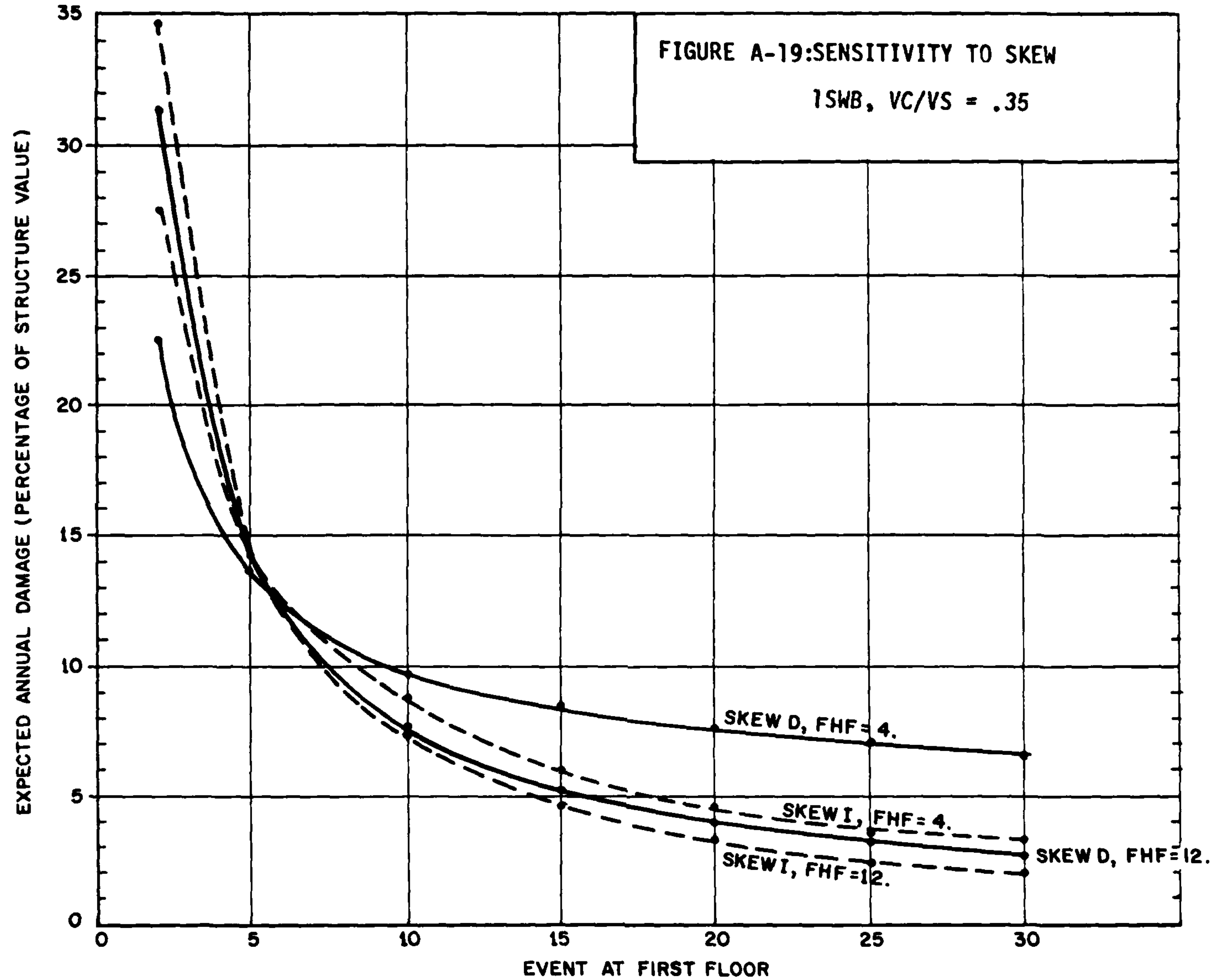


FIGURE A-19:SENSITIVITY TO SKEW

1SWB, VC/VS = .35

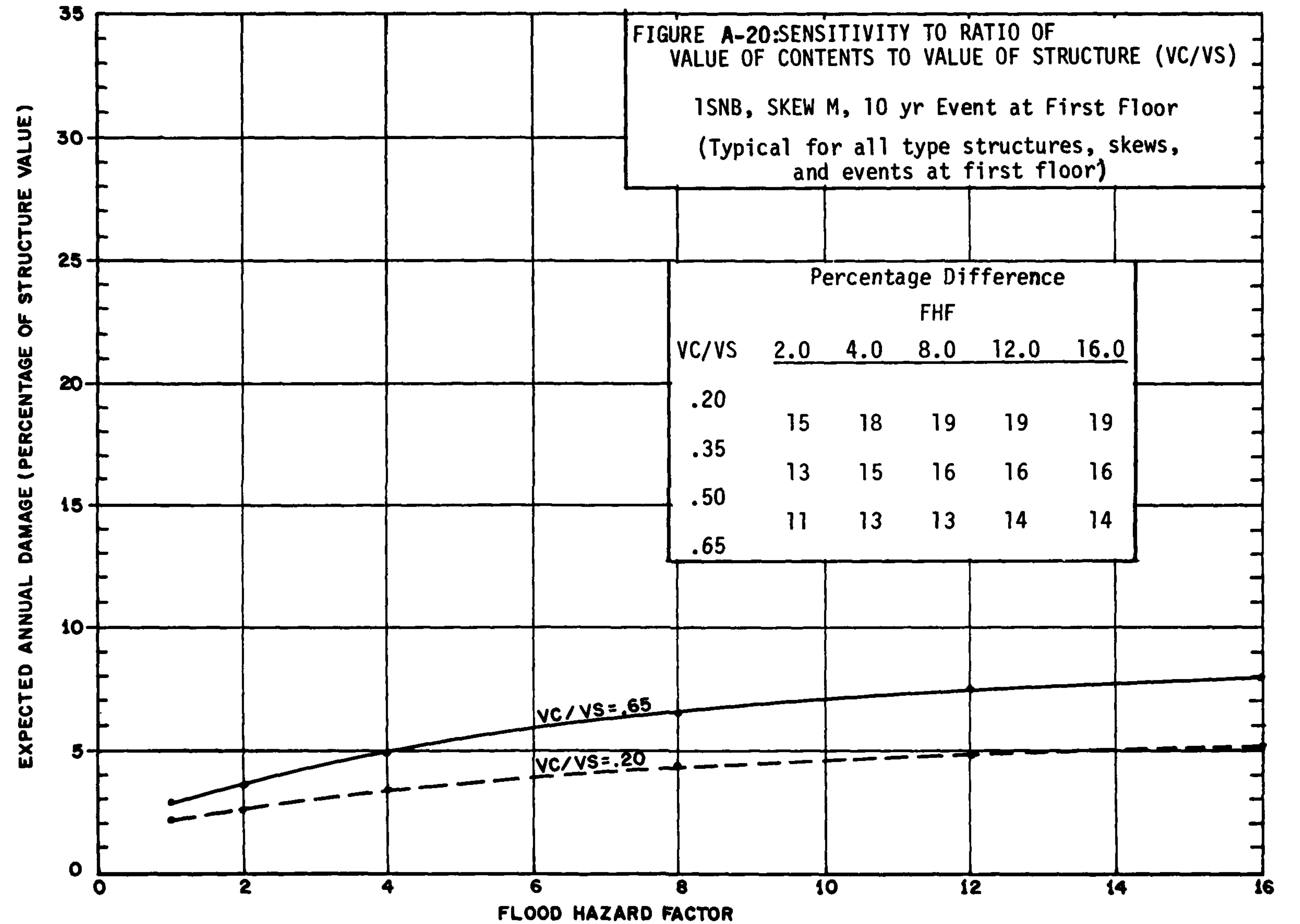


FIGURE A-20: SENSITIVITY TO RATIO OF VALUE OF CONTENTS TO VALUE OF STRUCTURE (VC/VS)

1SNB, SKEW M, 10 yr Event at First Floor

(Typical for all type structures, skews, and events at first floor)

Percentage Difference

	FHF				
VC/VS	2.0	4.0	8.0	12.0	16.0
.20					
	15	18	19	19	19
.35					
	13	15	16	16	16
.50					
	11	13	13	14	14
.65					

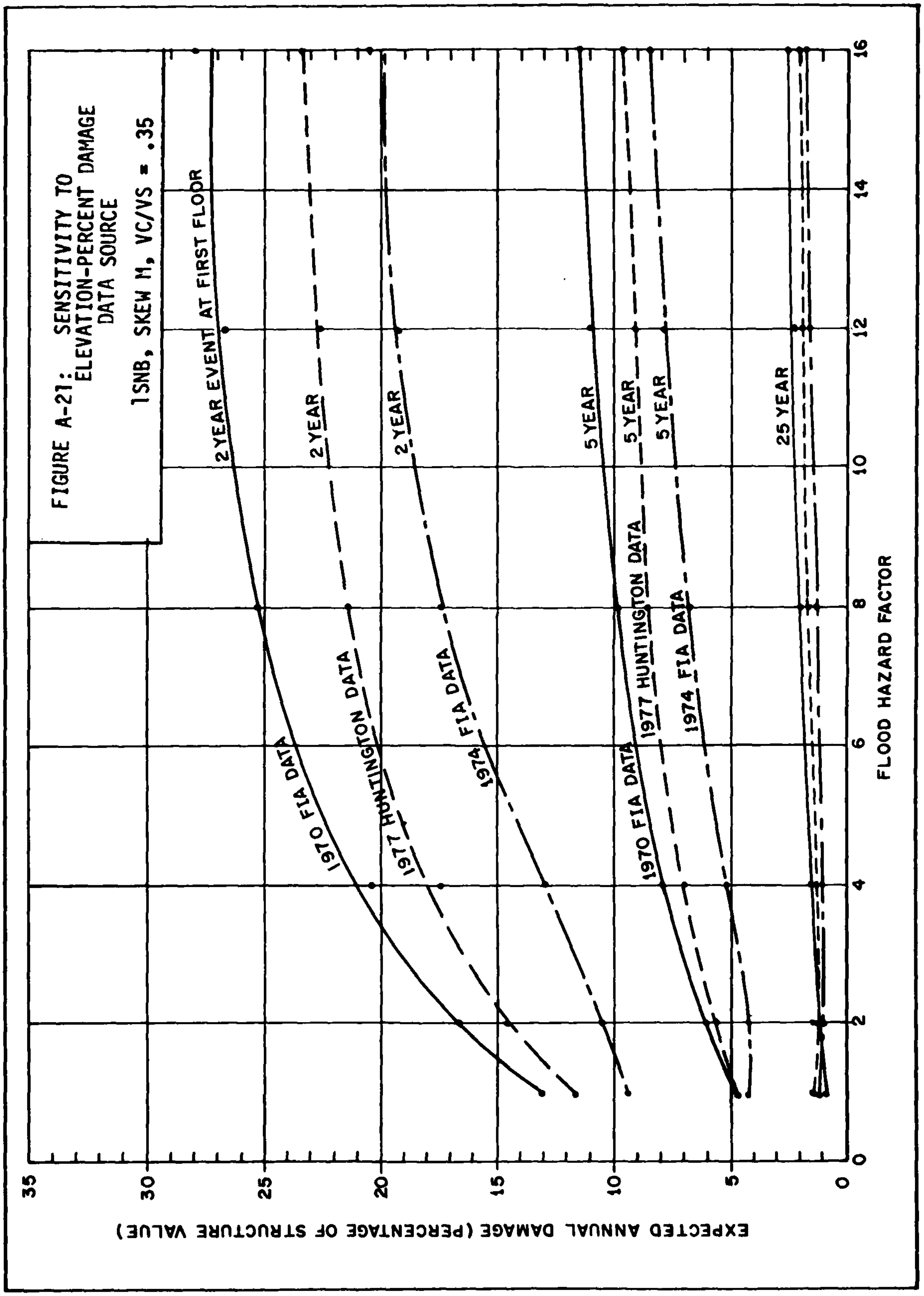


FIGURE A-21: SENSITIVITY TO ELEVATION-PERCENT DAMAGE DATA SOURCE

1SNB, SKEW M, VC/VS = .35

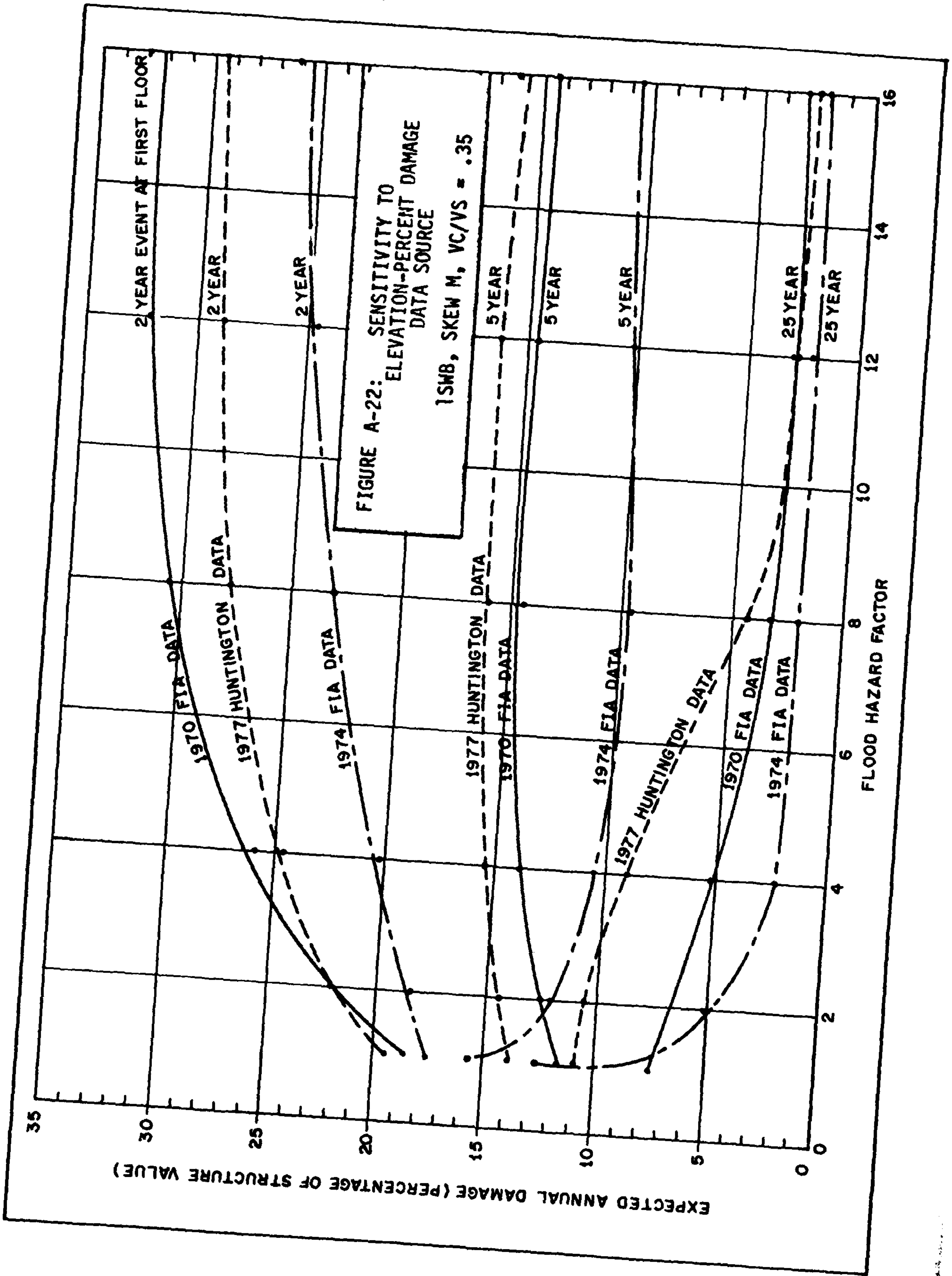


FIGURE A-22: SENSITIVITY TO ELEVATION-PERCENT DAMAGE DATA SOURCE

1SWB, SKEW M, VC/VS = .35

FIGURES AND TABLES
FOR DAMAGE REDUCED

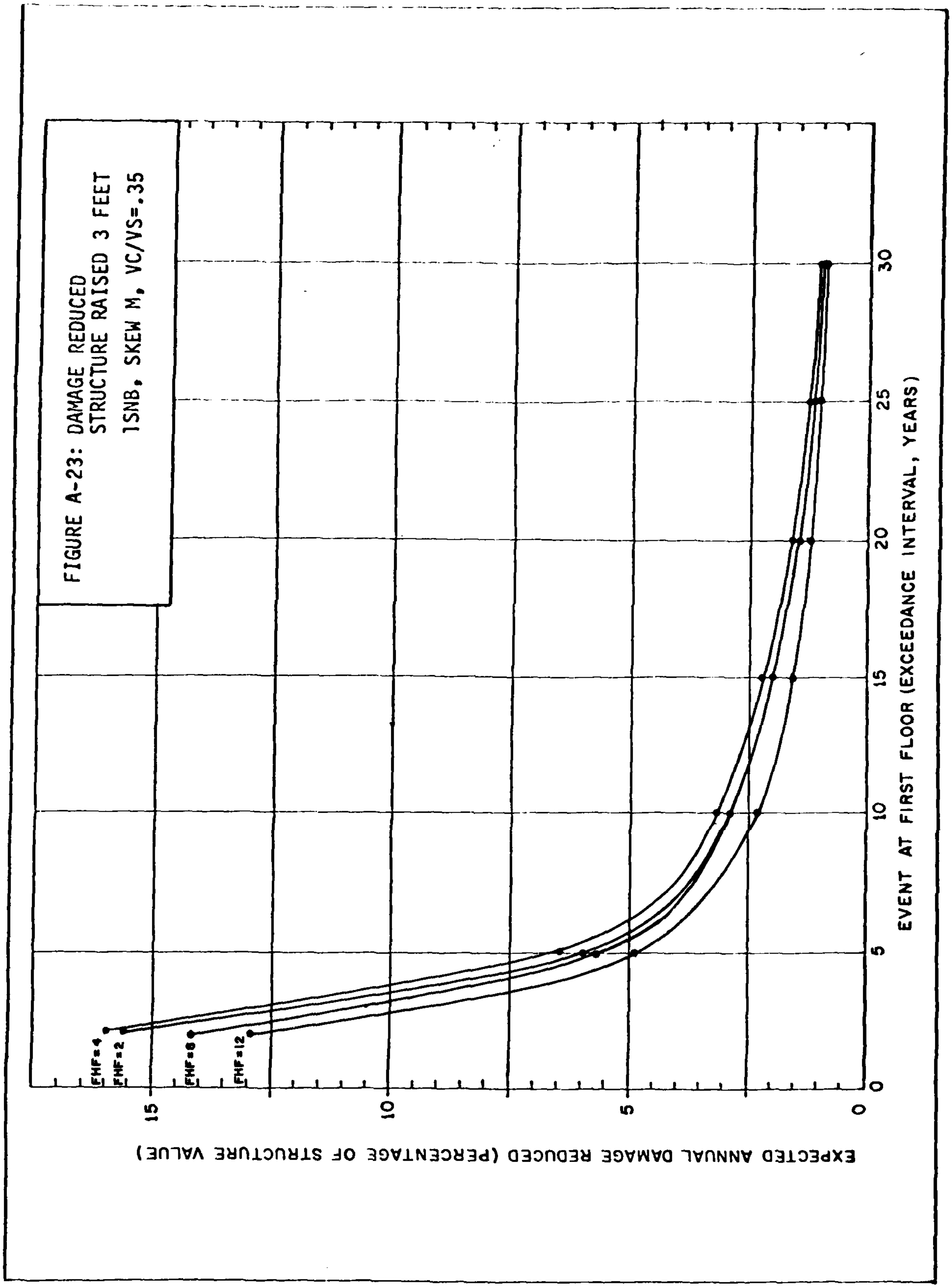


FIGURE A-23: DAMAGE REDUCED
STRUCTURE RAISED 3 FEET
1SNB, SKEW M, VC/VS=.35

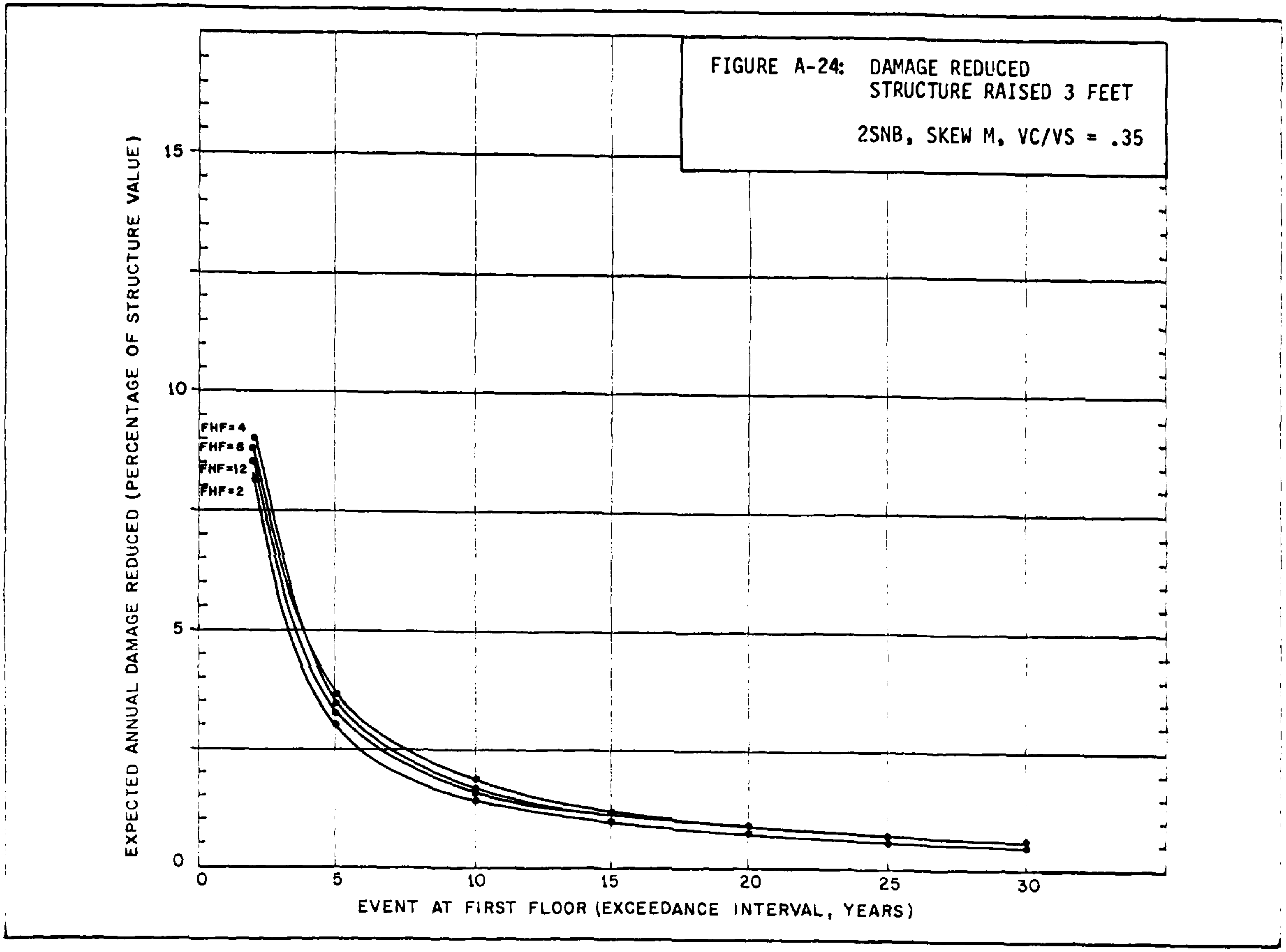


FIGURE A-24: DAMAGE REDUCED
STRUCTURE RAISED 3 FEET

2SNB, SKEW M, VC/VS = .35

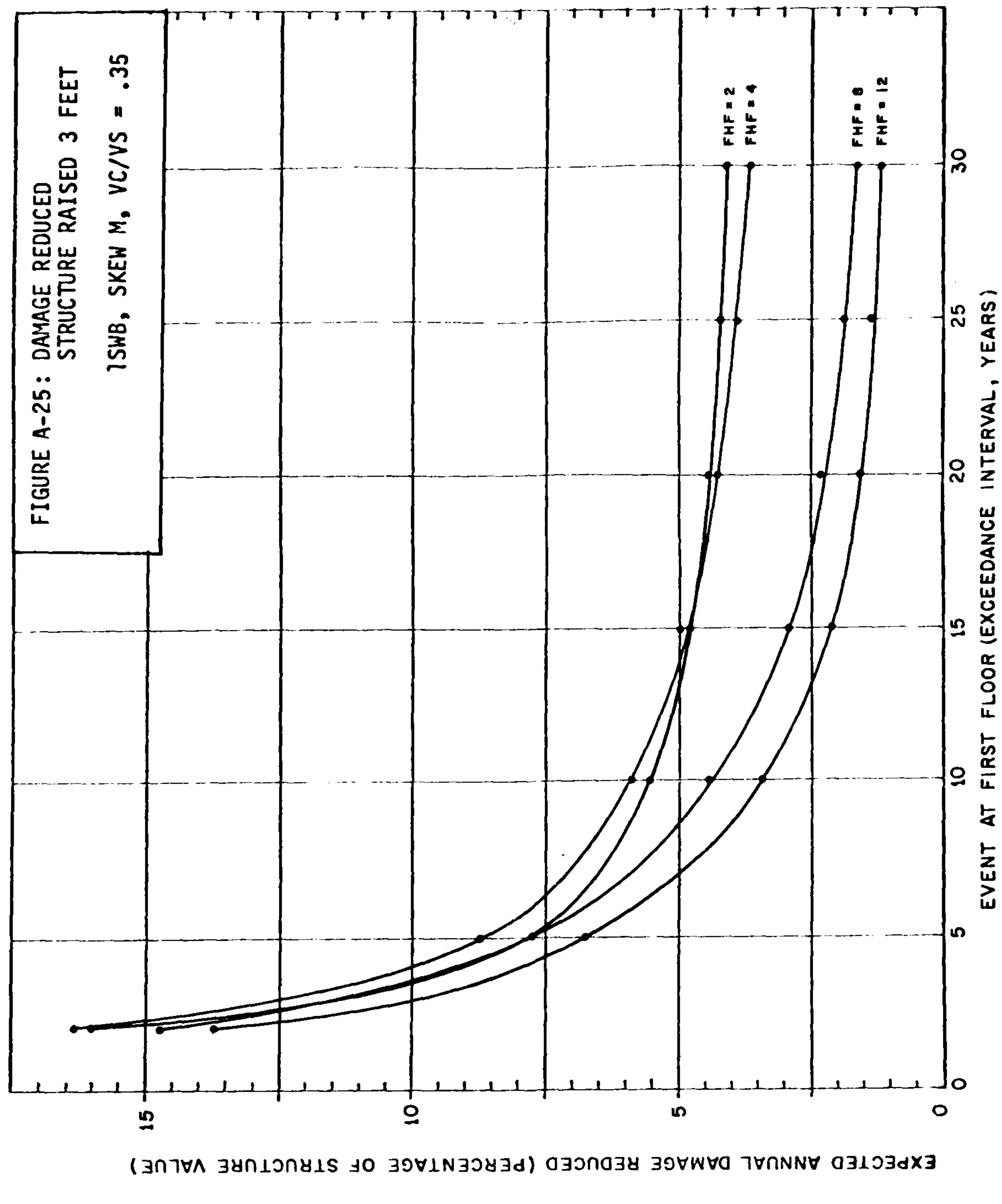


FIGURE A-25: DAMAGE REDUCED
STRUCTURE RAISED 3 FEET

1SWB, SKEW M, VC/VS = .35

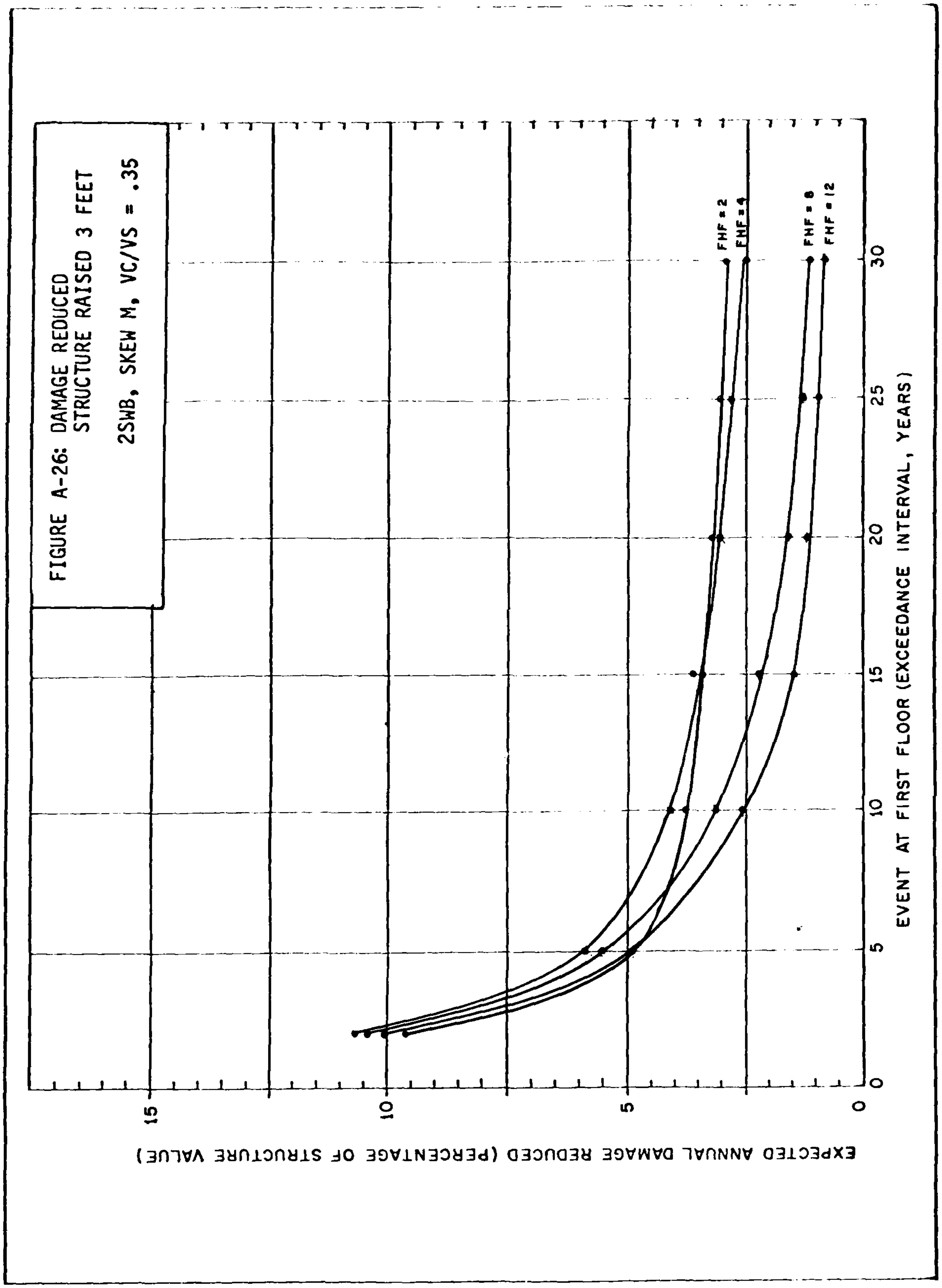
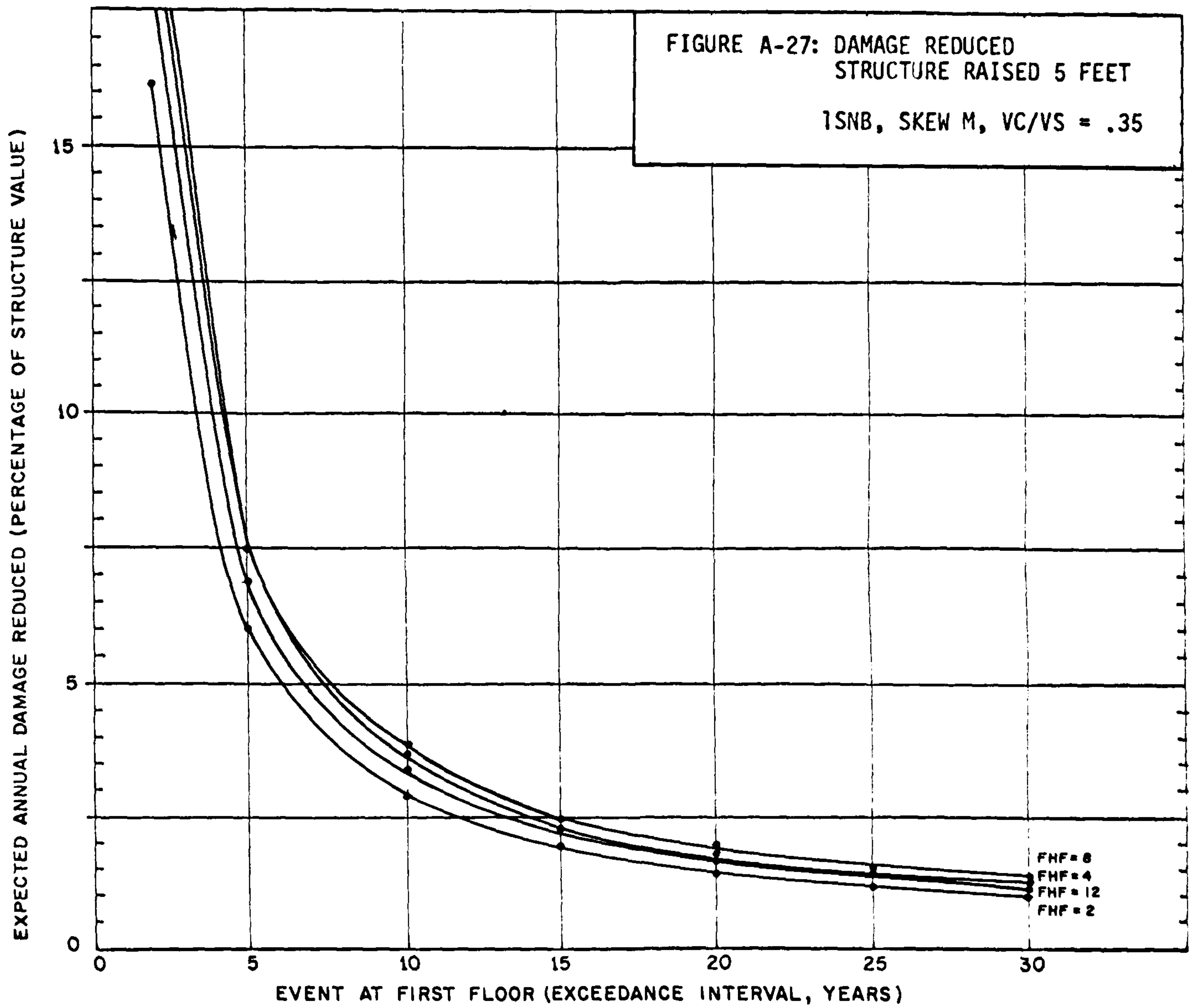


FIGURE A-26: DAMAGE REDUCED
STRUCTURE RAISED 3 FEET

2SWB, SKEW M, VC/VS = .35

FIGURE A-27: DAMAGE REDUCED
STRUCTURE RAISED 5 FEET

1SNB, SKEW M, VC/VS = .35



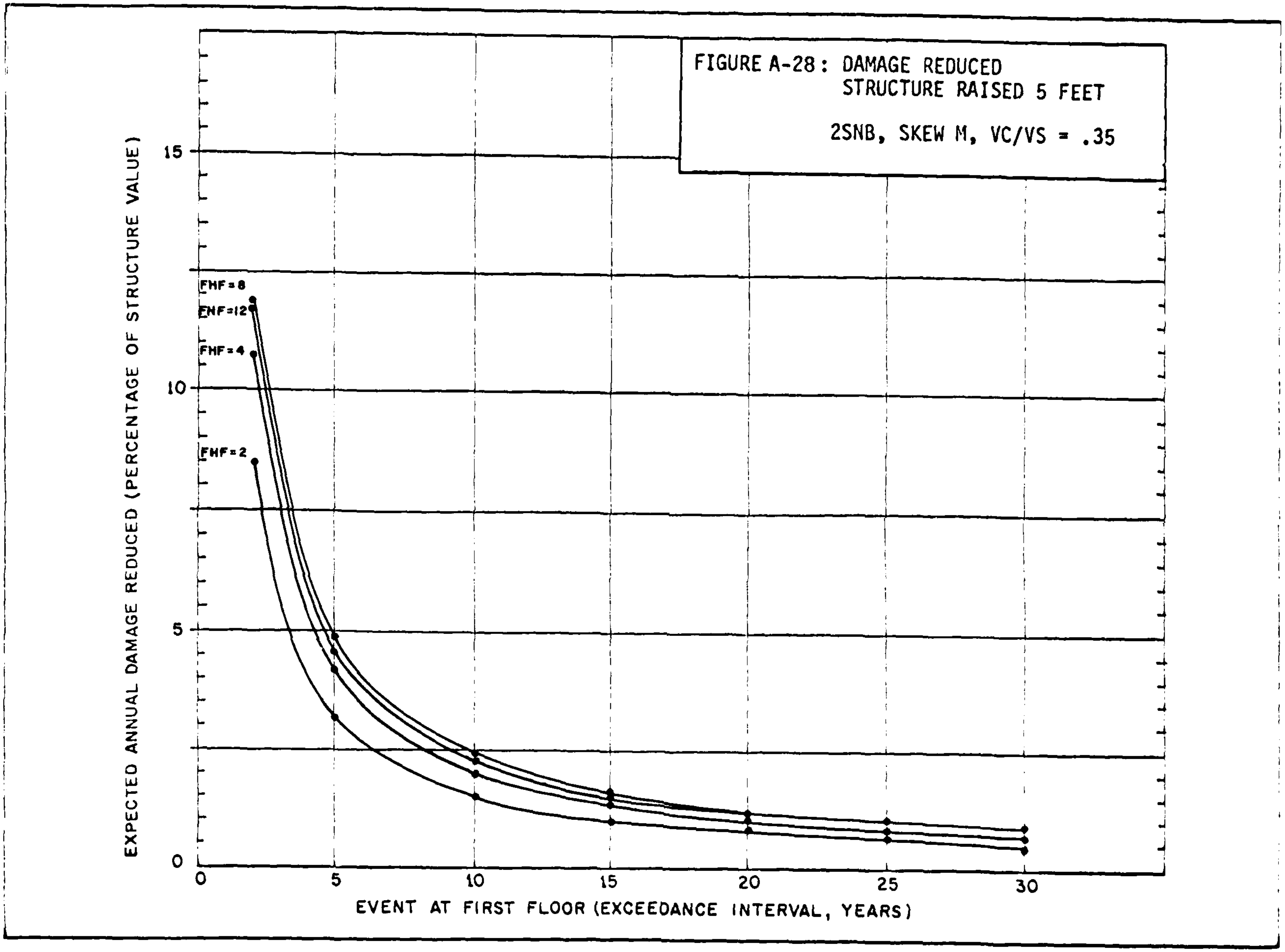


FIGURE A-28: DAMAGE REDUCED
STRUCTURE RAISED 5 FEET
2SNB, SKEW M, VC/VS = .35
FHF=8
FHF=12
FHF=4
FHF=2
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
15
10
5
0
0
5
10
15
20
25
30
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)

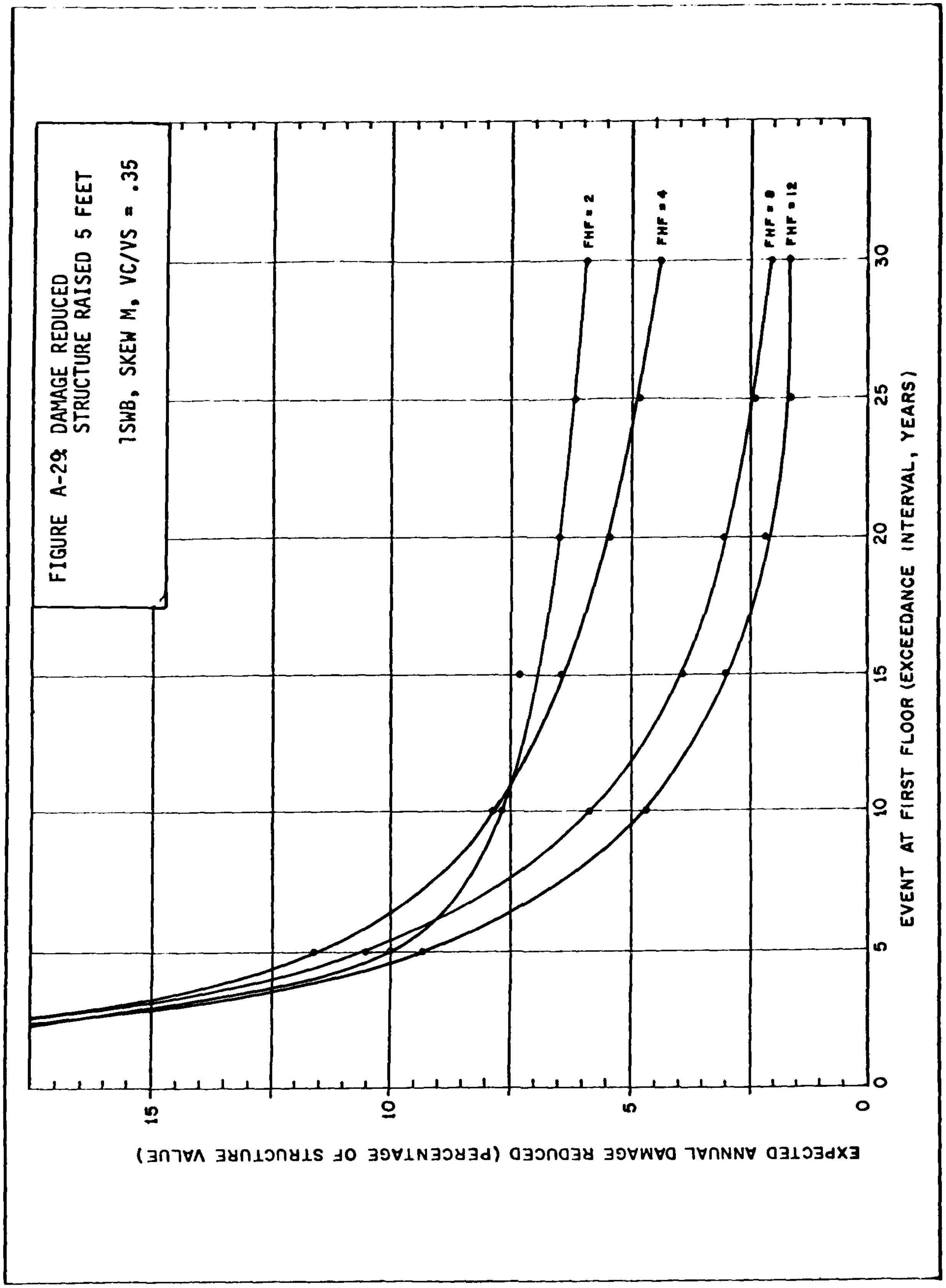
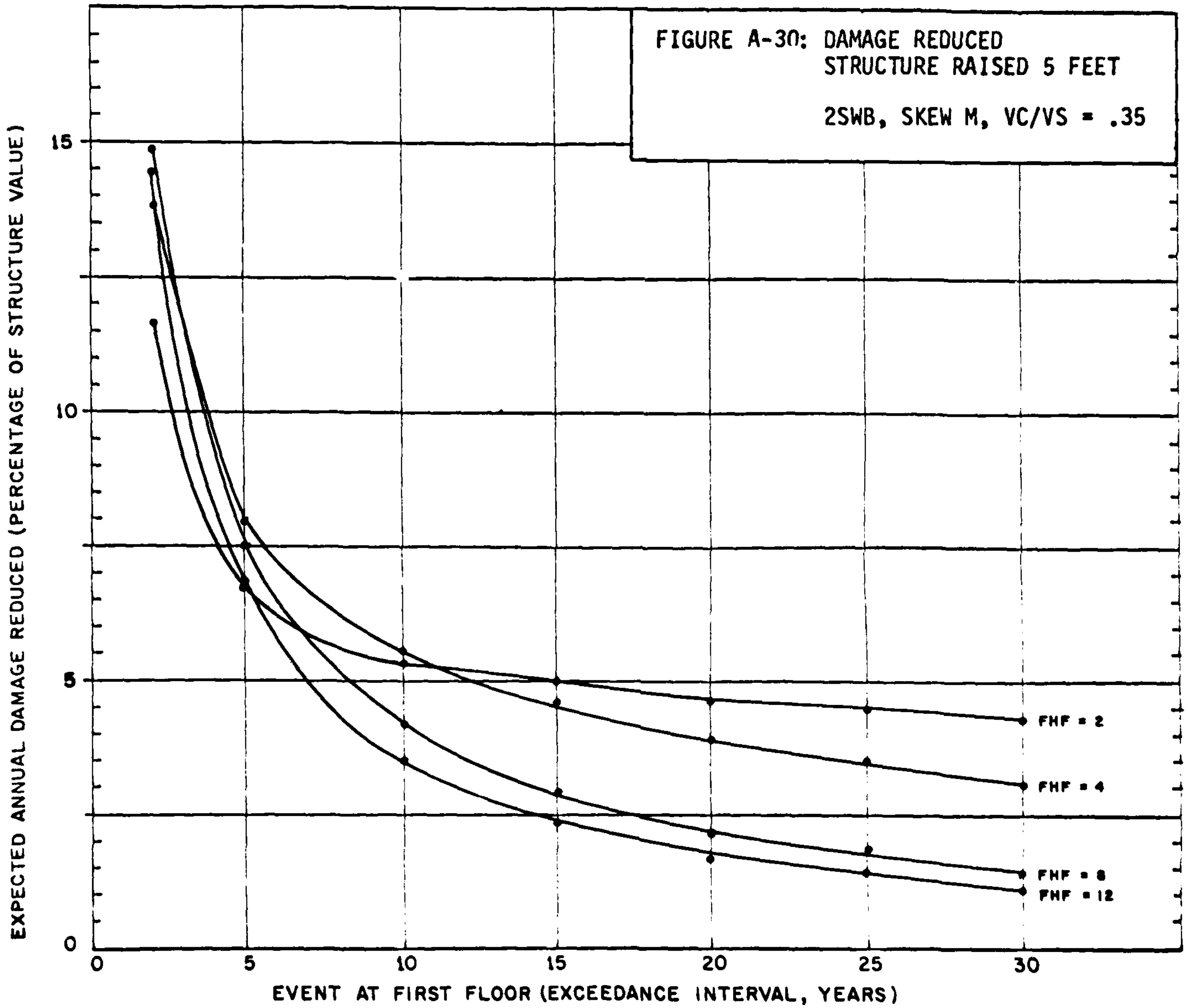


FIGURE A-29: DAMAGE REDUCED
STRUCTURE RAISED 5 FEET

1SWB, SKEW M, VC/VS = .35

FIGURE A-30: DAMAGE REDUCED
STRUCTURE RAISED 5 FEET

2SWB, SKEW M, VC/VS = .35



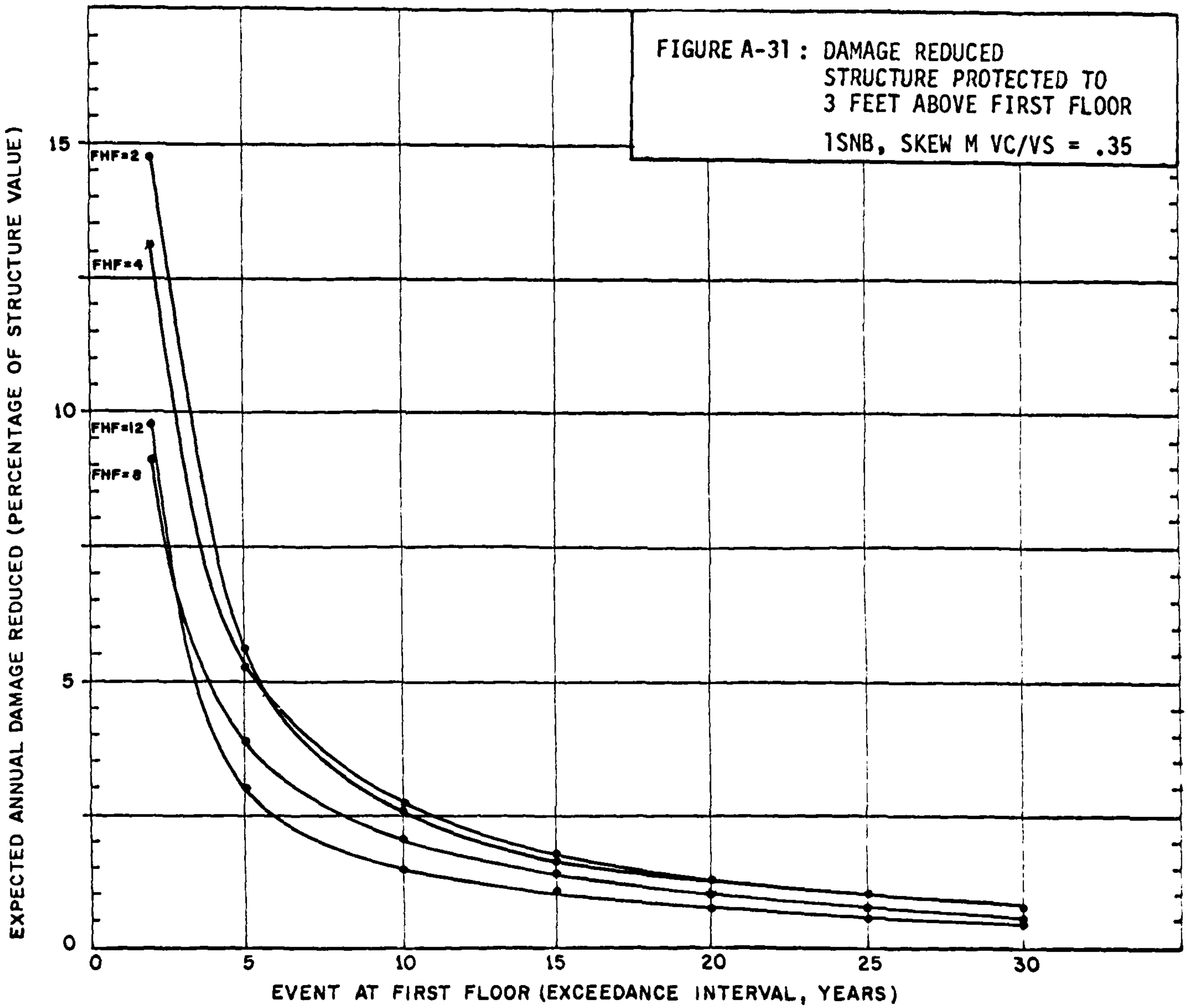


FIGURE A-31 : DAMAGE REDUCED
STRUCTURE PROTECTED TO
3 FEET ABOVE FIRST FLOOR

1SNB, SKEW M VC/VS = .35

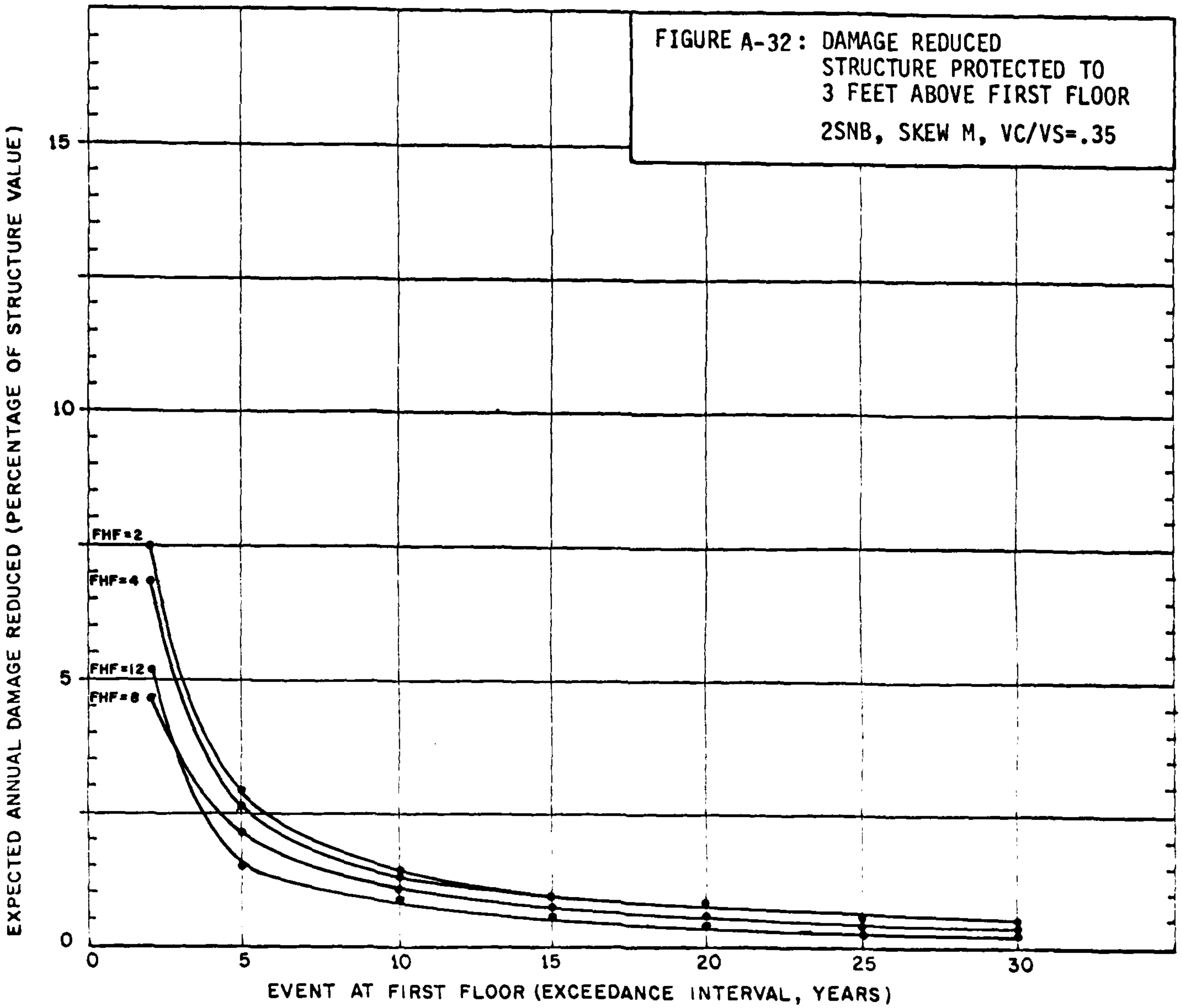


FIGURE A-32: DAMAGE REDUCED
STRUCTURE PROTECTED TO
3 FEET ABOVE FIRST FLOOR

2SNB, SKEW M, VC/VS=.35

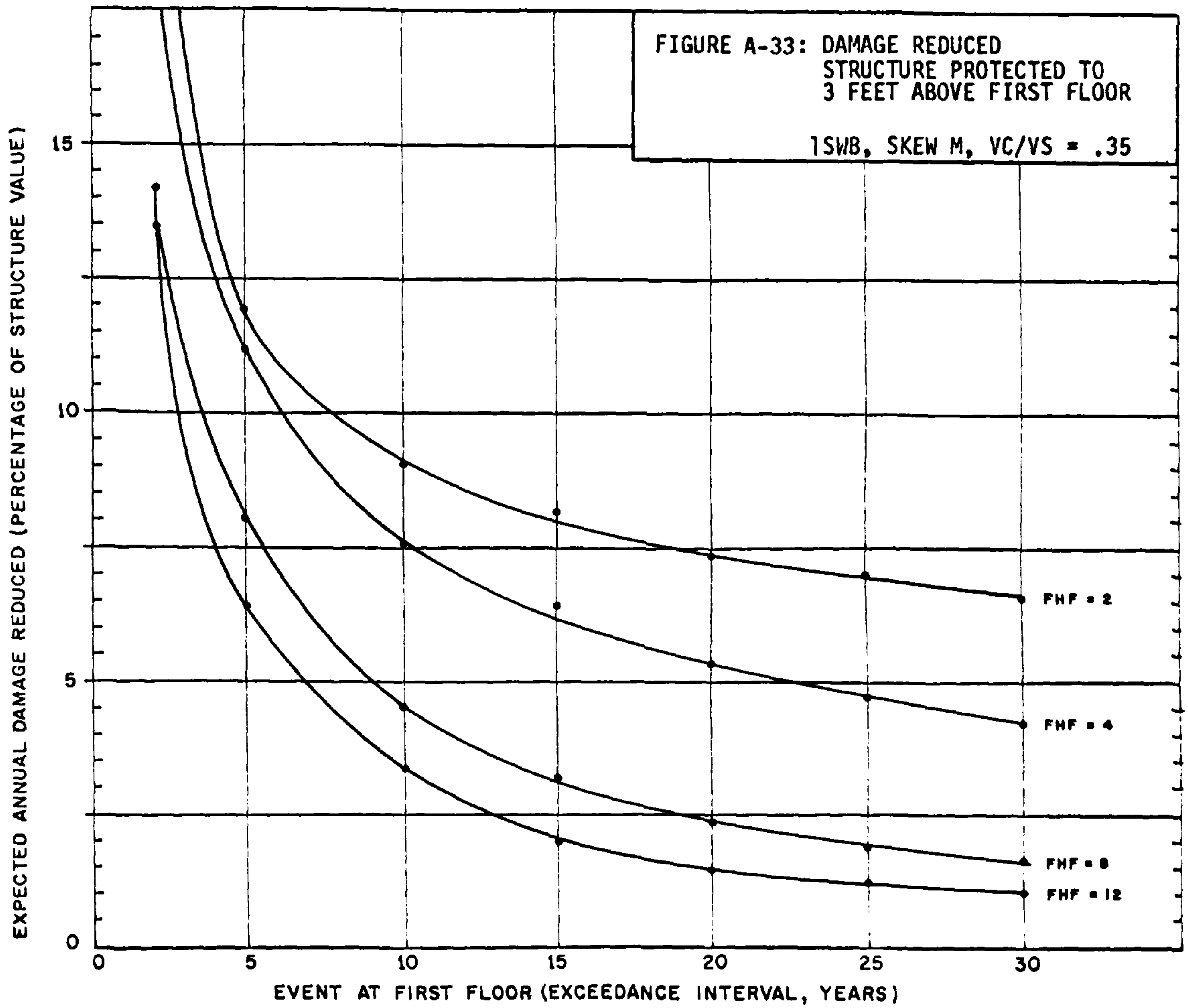


FIGURE A-33: DAMAGE REDUCED
STRUCTURE PROTECTED TO
3 FEET ABOVE FIRST FLOOR

1SWB, SKEW M, VC/VS = .35

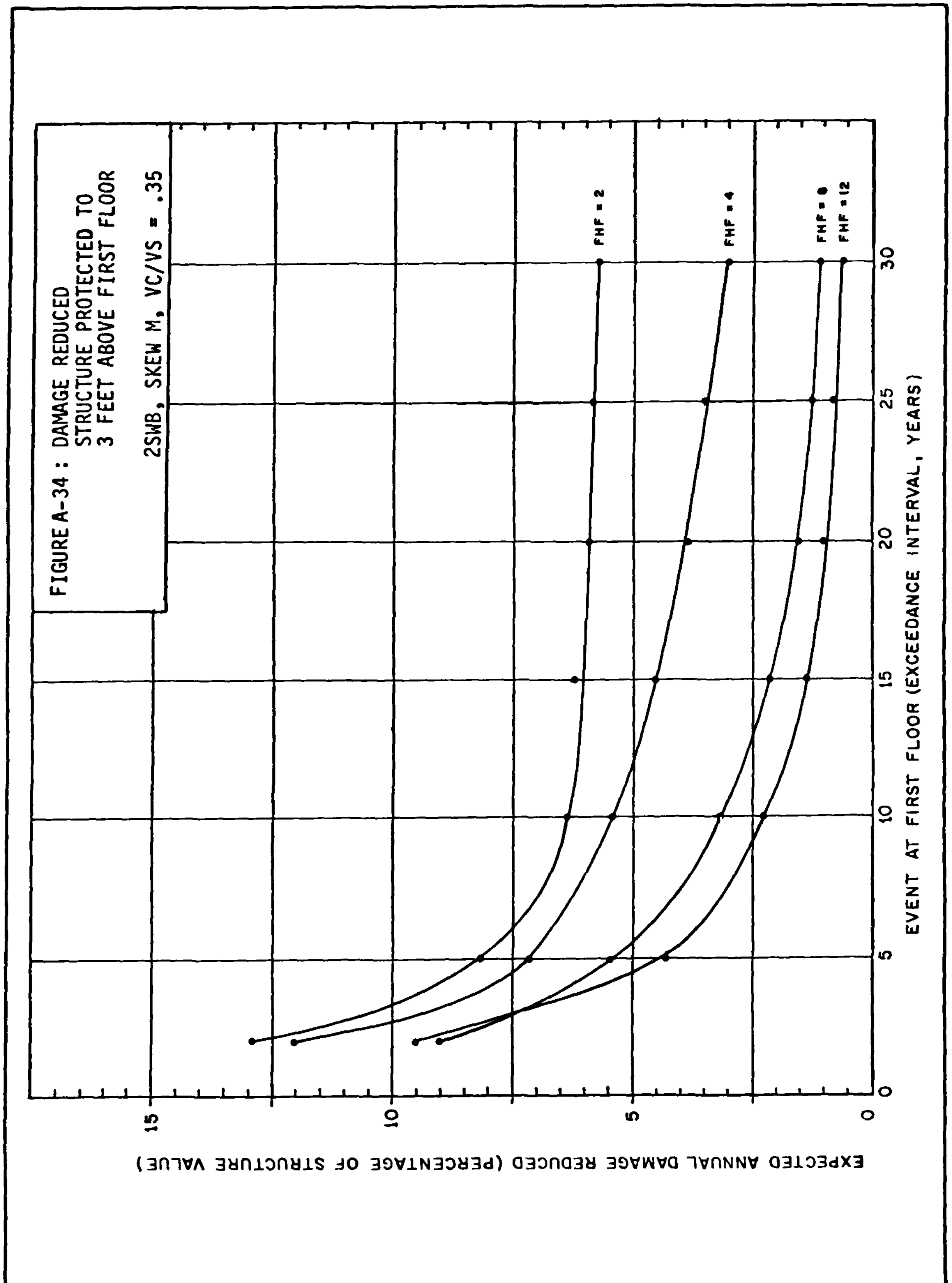


FIGURE A-34 : DAMAGE REDUCED STRUCTURE PROTECTED TO 3 FEET ABOVE FIRST FLOOR

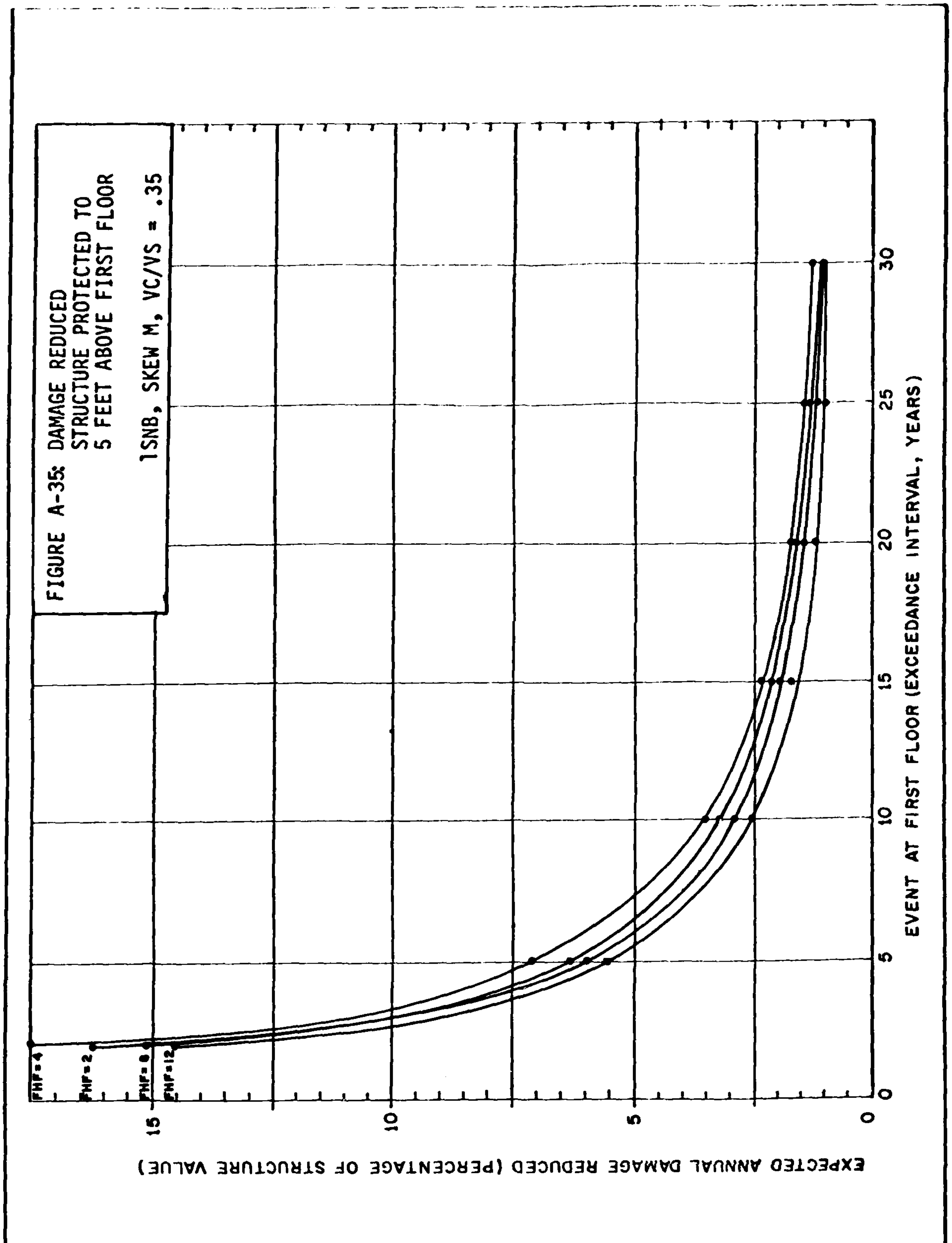


FIGURE A-35: DAMAGE REDUCED STRUCTURE PROTECTED TO 5 FEET ABOVE FIRST FLOOR

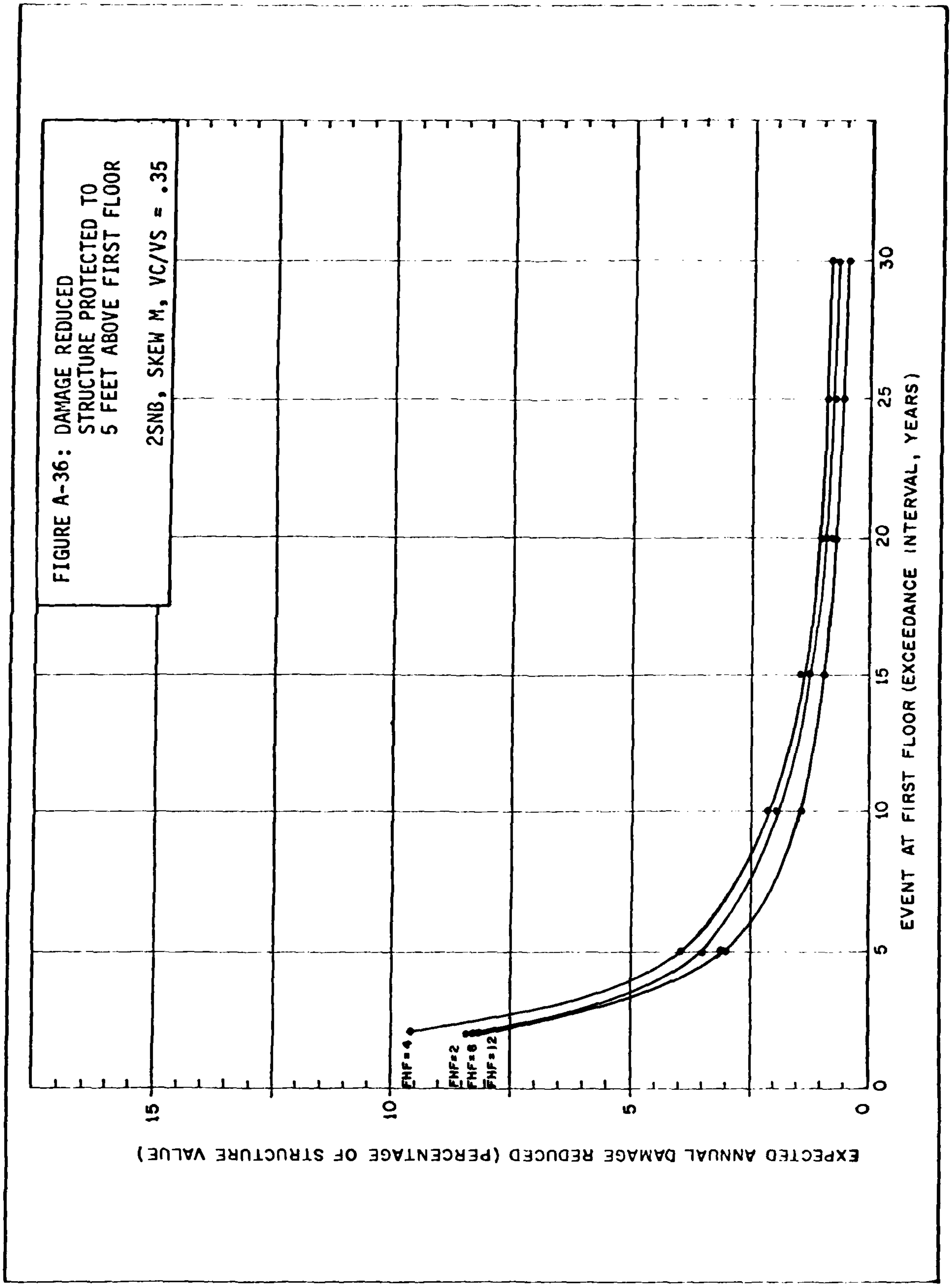


FIGURE A-36: DAMAGE REDUCED
STRUCTURE PROTECTED TO
5 FEET ABOVE FIRST FLOOR

2SNB, SKEW M, VC/VS = .35

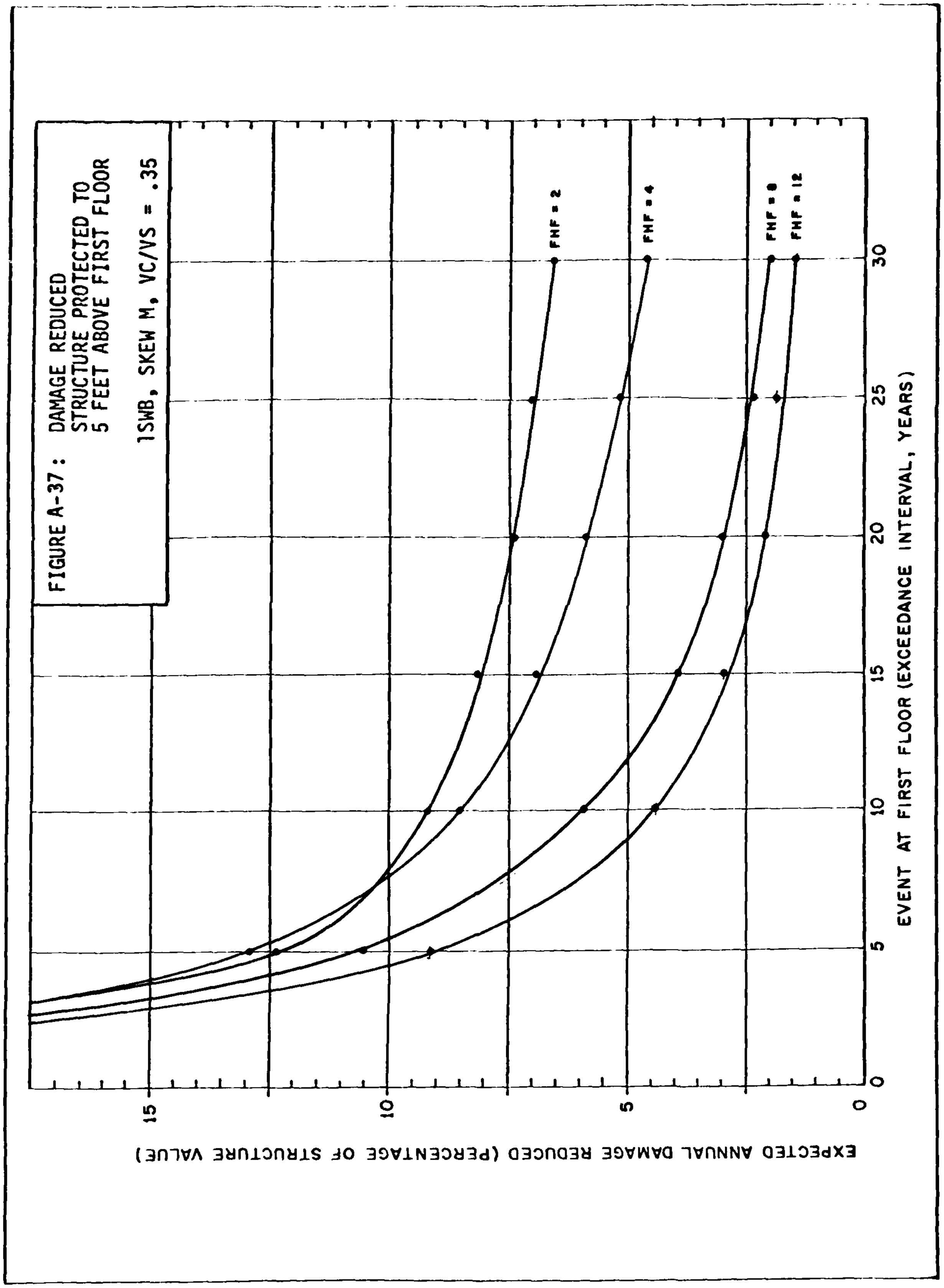


FIGURE A-37 : DAMAGE REDUCED
STRUCTURE PROTECTED TO
5 FEET ABOVE FIRST FLOOR
1SWB, SKEW M, VC/VS = .35
FHF = 2
FHF = 4
FHF = 8
FHF = 12
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
0
5
10
15
20
25
30

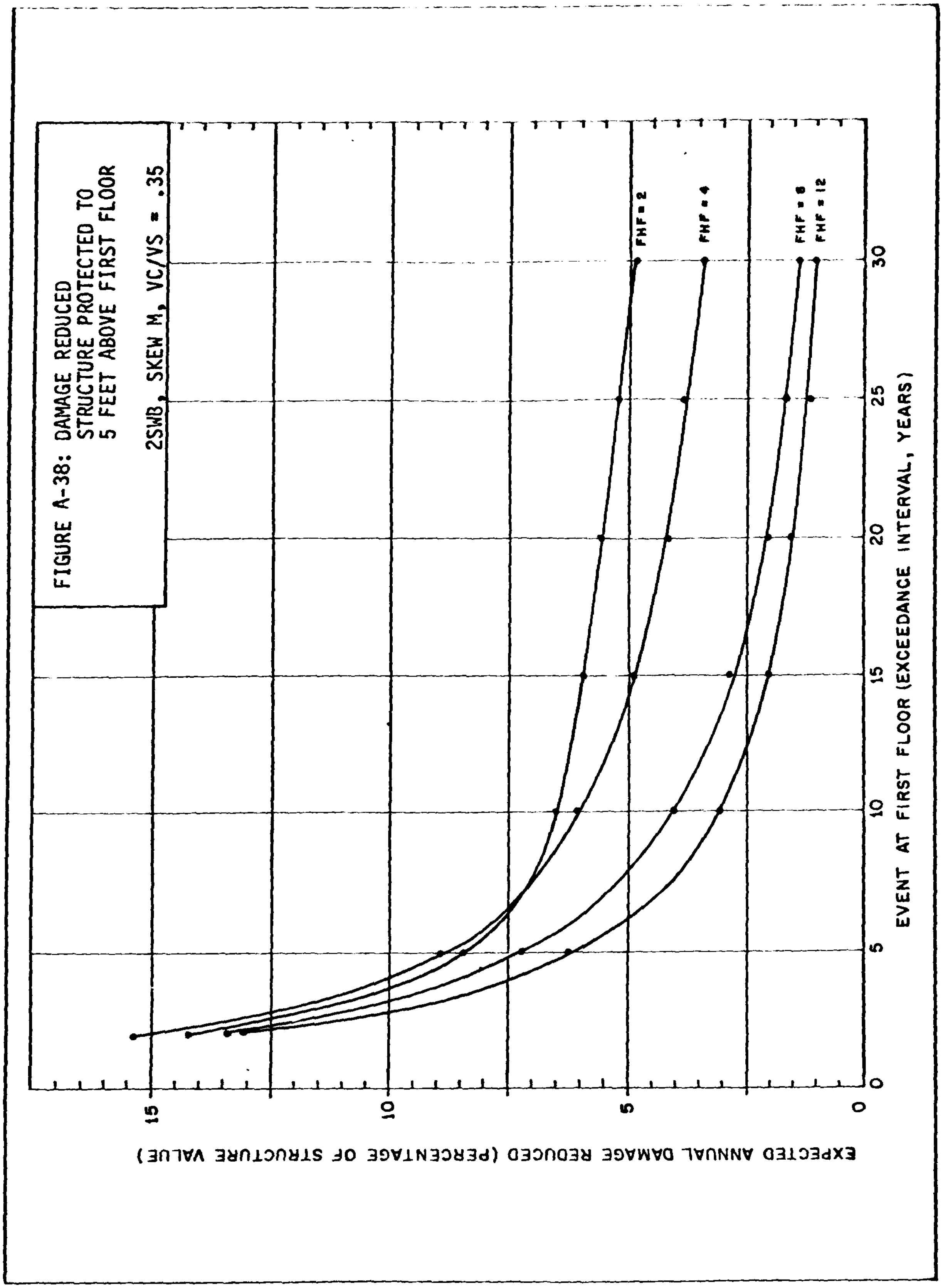


FIGURE A-38: DAMAGE REDUCED
STRUCTURE PROTECTED TO
5 FEET ABOVE FIRST FLOOR

2SWB, SKEW M, VC/VS = .35

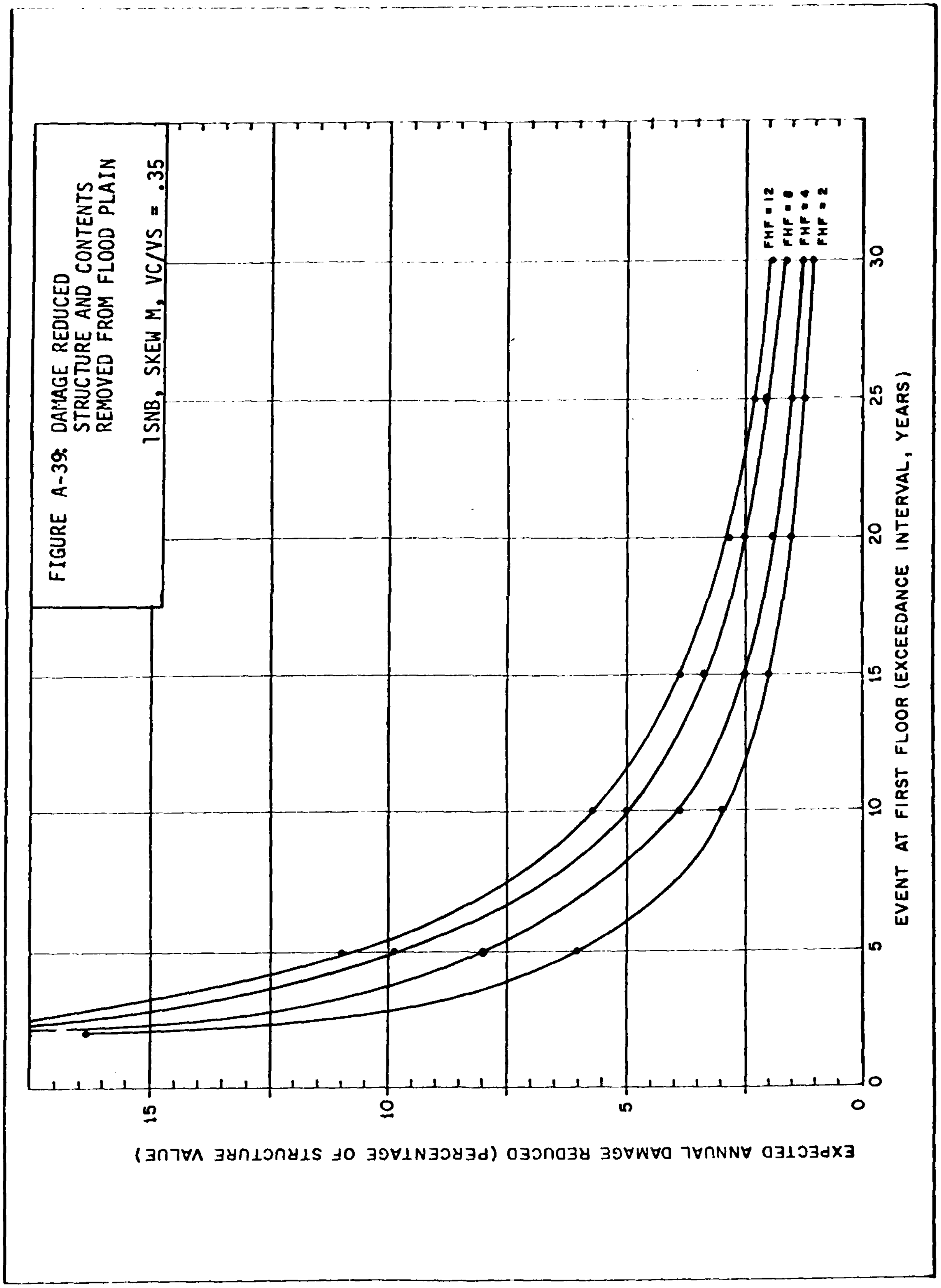


FIGURE A-39: DAMAGE REDUCED STRUCTURE AND CONTENTS REMOVED FROM FLOOD PLAIN

1SNB, SKEW M, VC/VS = .35

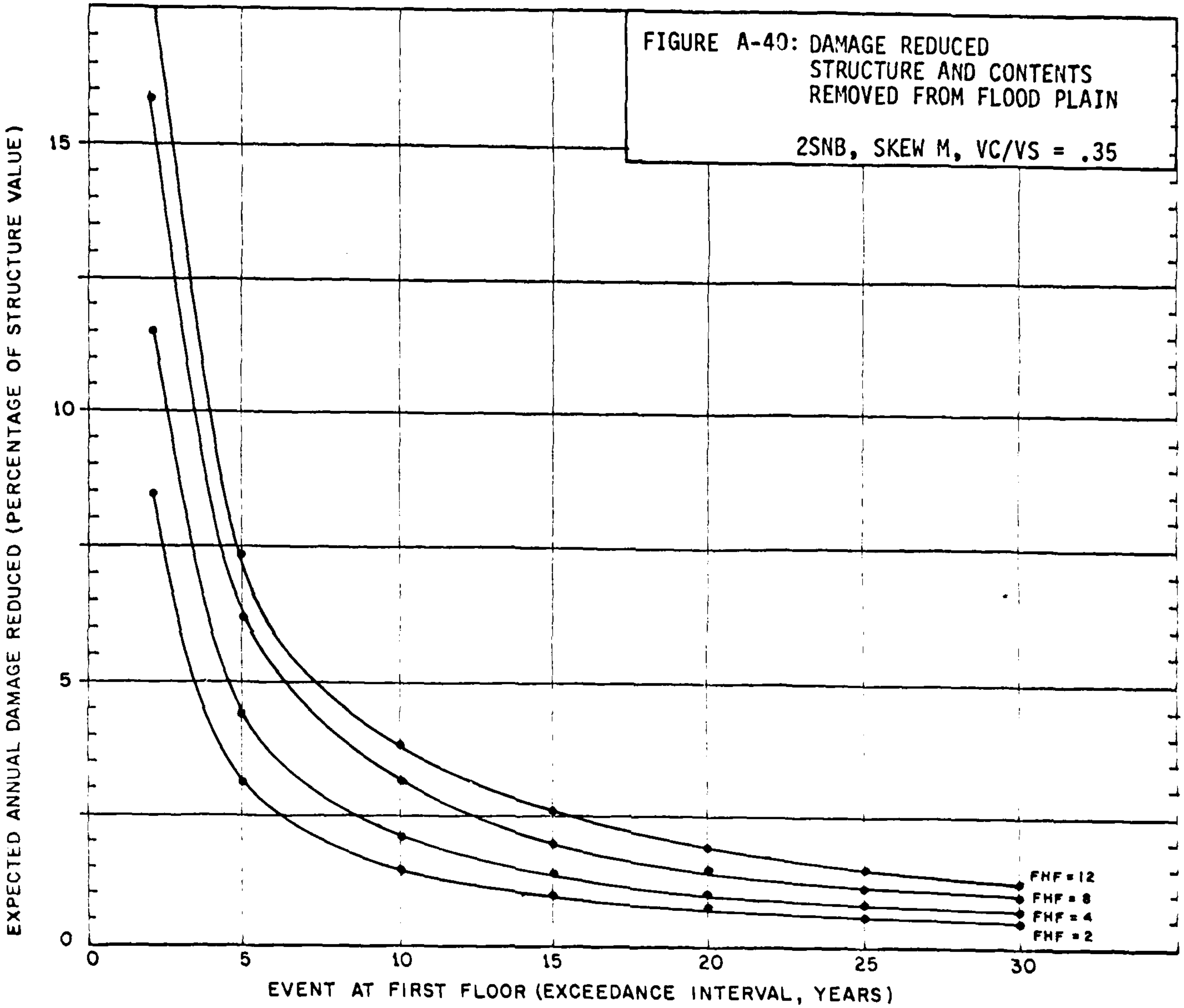


FIGURE A-40: DAMAGE REDUCED
STRUCTURE AND CONTENTS
REMOVED FROM FLOOD PLAIN
2SNB, SKEW M, VC/VS = .35
EXPECTED ANNUAL DAMAGE REDUCED (PERCENTAGE OF STRUCTURE VALUE)
0
5
10
15
EVENT AT FIRST FLOOR (EXCEEDANCE INTERVAL, YEARS)
0
5
10
15
20
25
30
FHF = 12
FHF = 8
FHF = 4
FHF = 2

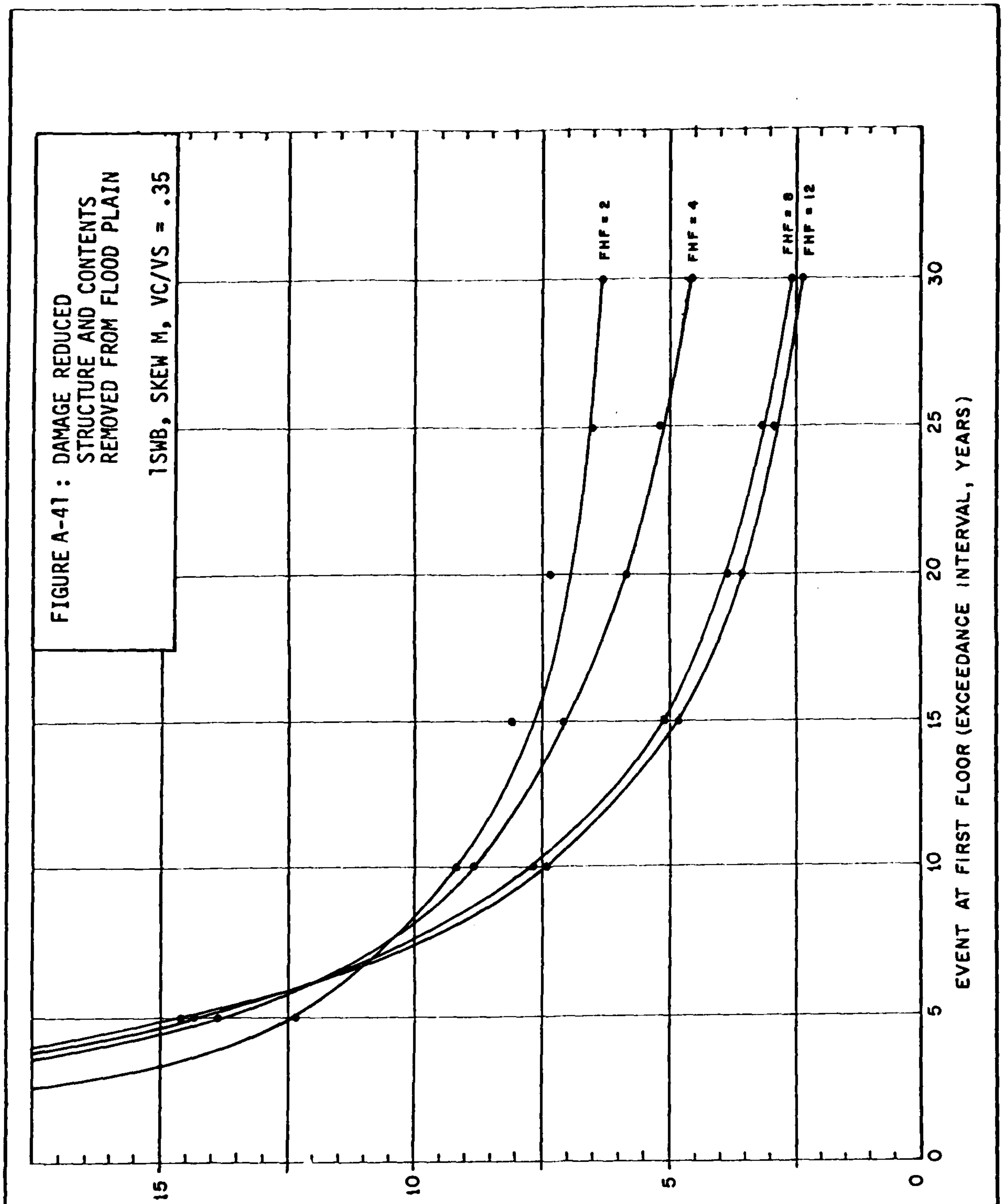


FIGURE A-41 : DAMAGE REDUCED
STRUCTURE AND CONTENTS
REMOVED FROM FLOOD PLAIN

1SWB, SKEW M, VC/VS = .35

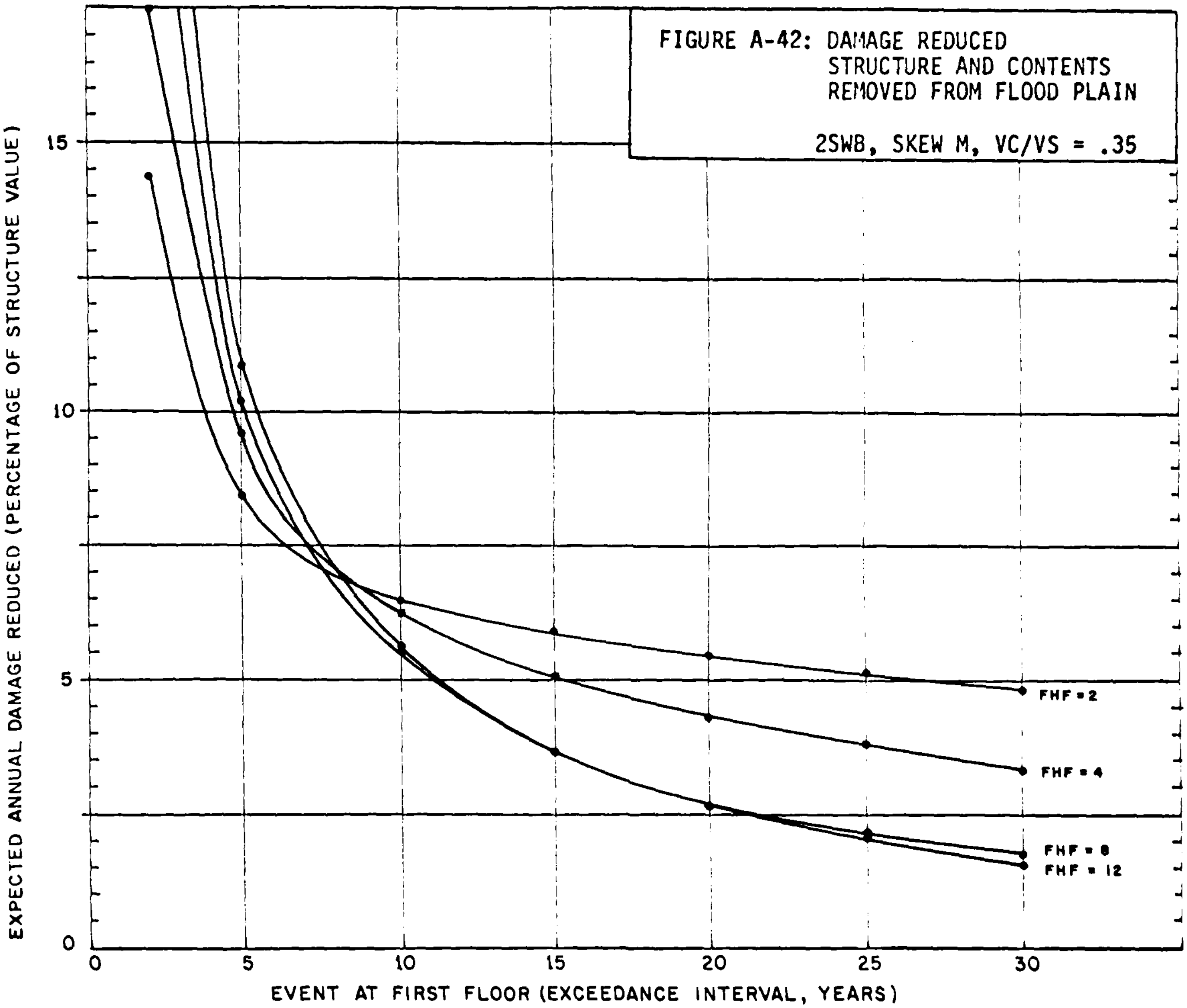


FIGURE A-42: DAMAGE REDUCED
STRUCTURE AND CONTENTS
REMOVED FROM FLOOD PLAIN

2SWB, SKEW M, VC/VS = .35

TABLE A-4

EXPECTED ANNUAL DAMAGE REDUCED[1 2]

RAISING STRUCTURE THREE FEET[3]

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
2 YR EVENT AT FIRST FLOOR				
1.0	13.0	6.5	13.1	7.6
2.0	15.6	8.1	15.9	9.6
4.0	15.9	9.0	16.3	10.6
8.0	14.1	8.8	14.7	10.4
12.0	12.9	8.5	13.7	10.0
16.0	11.8	8.0	12.5	9.4
20.0	12.7	8.3	13.5	9.8
5 YR EVENT AT FIRST FLOOR				
1.0	4.8	2.4	6.6	4.2
2.0	5.8	3.0	7.7	4.9
4.0	6.4	3.5	8.6	5.8
8.0	5.6	3.6	7.7	5.5
12.0	4.9	3.3	6.7	4.9
16.0	4.5	3.1	6.0	4.5
20.0	4.5	3.0	6.5	4.8
10 YR EVENT AT FIRST FLOOR				
1.0	2.4	1.2	4.8	3.3
2.0	2.9	1.5	5.5	3.7
4.0	3.2	1.7	5.9	4.1
8.0	2.9	1.8	4.4	3.1
12.0	2.3	1.6	3.3	2.5
16.0	2.0	1.5	2.8	2.1
20.0	2.0	1.4	2.9	2.2
15 YR EVENT AT FIRST FLOOR				
1.0	1.7	.9	4.3	3.1
2.0	2.0	1.0	4.8	3.4
4.0	2.2	1.2	5.0	3.6
8.0	1.9	1.2	2.9	2.2
12.0	1.6	1.2	2.1	1.7
16.0	1.4	1.1	1.7	1.4
20.0	1.2	.9	1.6	1.3
20 YR EVENT AT FIRST FLOOR				
1.0	1.3	.7	4.0	2.9
2.0	1.5	.8	4.4	3.2
4.0	1.6	.9	4.3	3.1
8.0	1.5	.9	2.3	1.6
12.0	1.2	.9	1.6	1.2
16.0	1.0	.8	1.2	1.0
20.0	.9	.7	1.1	.9

TABLE A-4 (Continued)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		25 YR EVENT AT FIRST FLOOR		
1.0	1.1	.5	3.8	2.9
2.0	1.2	.6	4.2	3.0
4.0	1.3	.7	3.9	2.8
8.0	1.2	.7	1.8	1.3
12.0	1.0	.7	1.3	1.0
16.0	.9	.6	1.0	.8
20.0	.7	.6	.8	.6
		30 YR EVENT AT FIRST FLOOR		
1.0	.9	.5	3.7	2.9
2.0	1.0	.5	4.0	2.9
4.0	1.0	.6	3.5	2.5
8.0	1.0	.6	1.5	1.1
12.0	.9	.6	1.1	.8
16.0	.7	.5	.9	.7
20.0	.6	.5	.6	.6
		50 YR EVENT AT FIRST FLOOR		
1.0	.5	.3	3.6	2.6
2.0	.6	.3	3.7	2.7
4.0	.6	.4	2.5	1.9
8.0	.6	.4	1.0	.7
12.0	.6	.4	.7	.5
16.0	.5	.4	.6	.4
20.0	.4	.3	.4	.4
		100 YR EVENT AT FIRST FLOOR		
1.0	.3	.1	3.5	2.6
2.0	.3	.1	3.5	2.6
4.0	.4	.2	1.5	1.1
8.0	.4	.2	.6	.3
12.0	.3	.2	.4	.3
16.0	.3	.2	.3	.2
20.0	.3	.1	.3	.3

[1]1970 FIA Depth-Damage Data, Skew M, VC/VS = .35.

[2]See "Computational Accuracy", Appendix A for a discussion of the accuracy of these data.

[3]Damage Reduced = Total Damage — Damage with structure (including basement) raised three feet. The values in the Table are total expected annual damage reduced (structure and contents) expressed as a percentage of structure value. To compute damage reduced in dollars, convert the Table value from percentage to decimal (e.g. 5.0 to .05) and multiply by the value of the structure (e.g. .05 x $35,000. = $1,750.). The value $1,750. is the expected annual damage reduced (structure and contents) for the flood hazard and damageable property assumed in the Table computations.

TABLE A-5

EXPECTED ANNUAL DAMAGE REDUCED[1 2]

RAISING STRUCTURE FIVE FEET[3]

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		2 YR EVENT AT FIRST FLOOR		
1.0	13.0	6.5	15.3	9.3
2.0	16.1	8.5	18.6	11.6
4.0	18.9	10.7	21.0	13.8
8.0	19.1	11.9	21.1	14.8
12.0	17.8	11.7	19.8	14.4
16.0	17.1	11.6	19.2	14.2
20.0	17.5	11.2	19.4	14.0
		5 YR EVENT AT FIRST FLOOR		
1.0	4.8	2.4	8.8	5.8
2.0	6.0	3.1	10.0	6.7
4.0	7.5	4.2	11.6	7.9
8.0	7.5	4.8	10.5	7.5
12.0	6.8	4.5	9.3	6.8
16.0	6.3	4.3	8.3	6.2
20.0	6.1	4.1	8.8	6.6
		10 YR EVENT AT FIRST FLOOR		
1.0	2.4	1.2	7.0	5.0
2.0	2.9	1.5	7.7	5.3
4.0	3.7	2.0	7.8	5.5
8.0	3.8	2.4	5.8	4.2
12.0	3.3	2.3	4.7	3.5
16.0	3.0	2.2	3.9	3.0
20.0	2.8	2.0	4.0	3.0
		15 YR EVENT AT FIRST FLOOR		
1.0	1.7	.9	6.5	4.7
2.0	2.0	1.0	7.3	5.0
4.0	2.5	1.4	6.4	4.6
8.0	2.5	1.6	3.9	2.9
12.0	2.3	1.7	3.0	2.3
16.0	2.0	1.5	2.5	2.0
20.0	1.8	1.4	2.3	1.8
		20 YR EVENT AT FIRST FLOOR		
1.0	1.3	.7	6.2	4.6
2.0	1.5	.8	6.4	4.7
4.0	1.9	1.0	5.4	3.9
8.0	2.0	1.2	3.0	2.1
12.0	1.7	1.[illegible]	2.2	1.7
16.0	1.5	1.[illegible]	1.8	1.4
20.0	1.3	1.1	1.6	1.3

TABLE A-5 (Continued)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		25 YR EVENT AT FIRST FLOOR		
1.0	1.1	.5	6.0	4.5
2.0	1.2	.6	6.1	4.5
4.0	1.5	.8	4.8	3.5
8.0	1.6	1.0	2.4	1.7
12.0	1.5	1.0	1.8	1.4
16.0	1.3	.9	1.5	1.2
20.0	1.1	.9	1.2	.9
		30 YR EVENT AT FIRST FLOOR		
1.0	.9	.5	6.0	4.4
2.0	1.0	.5	5.9	4.3
4.0	1.2	.7	4.3	3.0
8.0	1.3	.8	2.0	1.4
12.0	1.3	.8	1.6	1.1
16.0	1.1	.8	1.3	1.0
20.0	.9	.8	.9	.9
		50 YR EVENT AT FIRST FLOOR		
1.0	.5	.3	5.8	4.3
2.0	.6	.3	5.4	4.0
4.0	.7	.4	3.0	2.2
8.0	.9	.5	1.3	.9
12.0	.8	.5	1.0	.7
16.0	.8	.6	.8	.6
20.0	.6	.5	.6	.6
		100 YR EVENT AT FIRST FLOOR		
1.0	.3	.1	5.7	4.2
2.0	.3	.1	4.7	3.6
4.0	.4	.2	1.7	1.3
8.0	.5	.3	.7	.4
12.0	.5	.3	.6	.4
16.0	.4	.3	.5	.3
20.0	.5	.2	.5	.4

[1]1970 FIA Depth-Damage Data, Skew M. VC/VS = .35.

[2]See "Computational Accuracy", Appendix A for a discussion of the accuracy of these data.

[3]Damage Reduced = Total Damage — Damage with structure (including basement) raised five feet. The values in the Table are total expected annual damage reduced (structure and contents) expressed as a percentage of structure value. To compute damage reduced in dollars, convert the Table value from percentage to decimal (e.g. 5.0 to .05) and multiply by the value of the structure (e.g. .05 x $35,000. = $1,750.). The value $1,750. is the expected annual damage reduced (structure and contents) for the flood hazard and damageable property assumed in the Table computations.

TABLE A-6

EXPECTED ANNUAL DAMAGE REDUCED[1 2]

PROTECTING STRUCTURE THREE FEET[3]

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		2 YR EVENT AT FIRST FLOOR		
1.0	13.0	6.5	18.7	11.9
2.0	14.7	7.5	20.3	12.9
4.0	13.1	6.8	18.3	12.0
8.0	9.1	4.7	13.5	9.0
12.0	9.7	5.2	14.2	9.5
16.0	6.1	3.1	10.2	6.9
20.0	9.6	5.1	14.2	9.5
		5 YR EVENT AT FIRST FLOOR		
1.0	4.8	2.4	11.5	7.9
2.0	5.6	2.9	11.9	8.1
4.0	5.3	2.7	11.1	7.6
8.0	3.9	2.1	8.0	5.5
12.0	3.0	1.5	6.3	4.3
16.0	3.1	1.7	5.9	4.1
20.0	2.9	1.5	6.6	4.6
		10 YR EVENT AT FIRST FLOOR		
1.0	2.4	1.2	9.2	6.7
2.0	2.7	1.4	9.0	6.4
4.0	2.7	1.3	7.6	5.4
8.0	2.0	1.1	4.5	3.2
12.0	1.5	.8	3.3	2.3
16.0	1.3	.7	2.6	1.8
20.0	1.3	.6	2.9	2.0
		15 YR EVENT AT FIRST FLOOR		
1.0	1.7	.9	8.5	6.3
2.0	1.7	.9	8.1	6.3
4.0	1.9	1.0	6.3	4.6
8.0	1.4	.7	3.1	2.2
12.0	1.0	.6	2.0	1.4
16.0	.9	.5	1.6	1.1
20.0	.8	.4	1.5	1.0
		20 YR EVENT AT FIRST FLOOR		
1.0	1.3	.7	8.1	6.0
2.0	1.3	.7	7.4	6.0
4.0	1.4	.7	5.4	3.9
8.0	1.1	.5	2.4	1.6
12.0	.8	.4	1.5	1.1
16.0	.6	.3	1.0	.7
20.0	.5	.3	1.0	.7

TABLE A-6 (Continued)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		25 YR EVENT AT FIRST FLOOR		
1.0	1.1	.5	7.8	5.9
2.0	1.1	.5	7.0	5.9
4.0	1.1	.5	4.7	3.5
8.0	.8	.4	1.8	1.3
12.0	.7	.3	1.2	.8
16.0	.6	.2	.9	.6
20.0	.5	.3	.7	.5
		30 YR EVENT AT FIRST FLOOR		
1.0	.9	.5	7.7	5.7
2.0	.9	.5	6.6	5.7
4.0	.8	.5	4.2	3.0
8.0	.6	.4	1.6	1.1
12.0	.5	.3	1.0	.6
16.0	.4	.2	.8	.5
20.0	.4	.2	.5	.4
		50 YR EVENT AT FIRST FLOOR		
1.0	.5	.3	7.2	5.4
2.0	.5	.3	5.9	5.4
4.0	.5	.3	3.0	2.3
8.0	.5	.3	1.0	.7
12.0	.4	.2	.6	.4
16.0	.3	.2	.4	.3
20.0	.2	.1	.3	.2
		100 YR EVENT AT FIRST FLOOR		
1.0	.3	.1	6.8	5.1
2.0	.3	.1	5.0	5.1
4.0	.4	.2	1.8	1.4
8.0	.3	.1	.5	.3
12.0	.2	.1	.4	.3
16.0	.1	.1	.2	.1
20.0	.2	.1	.3	.2

[1]1970 FIA Depth-Damage Data, Skew M, VC/VS = .35.

[2]See "Computational Accuracy", Appendix A for a discussion of the accuracy of these data.

[3]Damage Reduced = Total Damage — Damage with structure (including basement) protected to three feet above first floor. The values in the Table are total expected annual damage reduced (structure and contents) expressed as a percentage of structure value. To compute damage reduced in dollars, convert the Table value from percentage to decimal (e.g. 5.0 to .05) and multiply by the value of the structure (e.g. .05 x $35,000. = $1,750.). The value $1,750. is the expected annual damage reduced (structure and contents) for the flood hazard and damageable property assumed in the Table computations.

TABLE A-7

EXPECTED ANNUAL DAMAGE REDUCED[1] [2]

PROTECTING STRUCTURE FIVE FEET[3]

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
2 YR EVENT AT FIRST FLOOR				
1.0	13.0	6.5	18.7	11.9
2.0	16.2	8.4	22.0	14.2
4.0	17.6	9.6	23.1	15.3
8.0	15.1	8.3	20.1	13.4
12.0	14.5	8.2	19.3	13.0
16.0	13.8	7.9	18.5	12.6
20.0	15.2	8.0	19.3	13.0
5 YR EVENT AT FIRST FLOOR				
1.0	4.8	2.4	11.5	7.9
2.0	6.0	3.1	12.3	8.4
4.0	7.1	3.8	12.9	8.9
8.0	6.3	3.5	10.5	7.2
12.0	5.5	3.0	9.1	6.2
16.0	5.2	2.9	8.2	5.6
20.0	5.0	2.8	8.8	6.1
10 YR EVENT AT FIRST FLOOR				
1.0	2.4	1.2	9.2	6.7
2.0	2.9	1.5	9.2	6.5
4.0	3.5	1.8	8.5	6.0
8.0	3.2	1.8	5.8	4.0
12.0	2.5	1.4	4.3	3.0
16.0	2.2	1.3	3.7	2.5
20.0	2.1	1.1	3.7	2.5
15 YR EVENT AT FIRST FLOOR				
1.0	1.7	.9	8.5	6.3
2.0	2.0	1.0	8.1	5.9
4.0	2.4	1.3	6.9	4.9
8.0	2.1	1.2	3.9	2.8
12.0	1.8	1.1	2.9	2.0
16.0	1.5	.9	2.2	1.5
20.0	1.3	.7	2.1	1.1
20 YR EVENT AT FIRST FLOOR				
1.0	1.3	.7	8.1	6.0
2.0	1.5	.8	7.4	5.5
4.0	1.7	.9	5.7	4.1
8.0	1.7	.9	3.0	2.0
12.0	1.3	.8	2.1	1.6
16.0	1.1	.6	1.6	1.1
20.0	1.0	.6	1.5	1.0

TABLE A-7 (Continued)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		25 YR EVENT AT FIRST FLOOR		
1.0	1.1	.5	7.8	5.9
2.0	1.2	.6	7.0	5.2
4.0	1.5	.8	5.2	3.8
8.0	1.3	.7	2.4	1.7
12.0	1.1	.6	1.7	1.1
16.0	.9	.4	1.3	.8
20.0	.8	.5	1.1	.7
		30 YR EVENT AT FIRST FLOOR		
1.0	.9	.5	7.7	5.7
2.0	1.0	.5	6.6	4.9
4.0	1.2	.7	4.6	3.3
8.0	1.0	.6	2.0	1.3
12.0	1.0	.5	1.5	1.0
16.0	.8	.4	1.2	.8
20.0	.6	.4	1.8	.6
		50 YR EVENT AT FIRST FLOOR		
1.0	.5	.3	7.2	5.4
2.0	.6	.3	5.9	4.4
4.0	.7	.4	3.2	2.4
8.0	.7	.4	1.3	.9
12.0	.6	.4	.9	.6
16.0	.6	.4	.8	.5
20.0	.4	.2	.6	.4
		100 YR EVENT AT FIRST FLOOR		
1.0	.3	.1	6.8	5.1
2.0	.3	.1	5.0	3.8
4.0	.4	.2	1.8	1.4
8.0	.5	.3	.8	.5
12.0	.3	.2	.5	.4
16.0	.3	.2	.4	.3
20.0	.3	.1	.4	.3

[1]1970 FIA Depth-Damage Data, Skew M, VC/VS = .35.

[2]See "Computational Accuracy", Appendix A for a discussion of the accuracy of these data.

[3]Damage Reduced = Total Damage — Damage with structure (including basement) protected to five feet above first floor. The values in the Table are total expected annual damage reduced (structure and contents) expressed as a percentage of structure value. To compute damage reduced in dollars, convert the Table value from percentage to decimal (e.g. 5.0 to .05) and multiply by the value of the structure (e.g. .05 x $35,000. = $1,750.). The value $1,750. is the expected annual damage reduced (structure and contents) for the flood hazard and damageable property assumed in the Table computations.

1970 FIA DATA

TABLE A-8

EXPECTED ANNUAL DAMAGE REDUCED[1,2]

REMOVING STRUCTURE AND CONTENTS FROM FLOOD HAZARD AREA[3]

(Equivalent to Total Damage)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		2 YR EVENT AT FIRST FLOOR		
1.0	13.0	6.5	18.7	11.9
2.0	16.4	8.5	22.2	14.3
4.0	20.4	11.5	26.1	17.5
8.0	25.3	15.8	30.6	21.7
12.0	26.8	17.8	31.9	23.4
16.0	28.1	19.3	33.1	24.8
20.0	26.7	17.9	31.9	23.6
		5 YR EVENT AT FIRST FLOOR		
1.0	4.8	2.4	11.5	7.9
2.0	6.0	3.1	12.3	8.4
4.0	8.0	4.4	13.9	9.6
8.0	9.9	6.2	14.3	10.2
12.0	10.9	7.3	14.6	10.8
16.0	11.3	8.0	14.4	11.0
20.0	11.1	7.9	15.0	11.5
		10 YR EVENT AT FIRST FLOOR		
1.0	2.4	1.2	9.2	6.7
2.0	2.9	1.5	9.2	6.5
4.0	3.9	2.1	8.9	6.3
8.0	5.0	3.1	7.7	5.5
12.0	5.6	3.8	7.5	5.6
16.0	6.0	4.4	7.5	5.8
20.0	6.1	4.5	7.8	6.1
		15 YR EVENT AT FIRST FLOOR		
1.0	1.7	.9	8.5	6.3
2.0	2.0	1.0	8.1	5.9
4.0	2.6	1.4	7.1	5.1
8.0	3.3	2.0	5.1	3.7
12.0	3.8	2.6	4.9	3.7
16.0	4.1	3.0	4.9	3.8
20.0	4.2	3.2	5.0	4.0
		20 YR EVENT AT FIRST FLOOR		
1.0	1.3	.7	8.1	6.0
2.0	1.5	.8	7.4	5.5
4.0	1.9	1.0	5.9	4.3
8.0	2.5	1.5	3.9	2.7
12.0	2.8	1.9	3.6	2.7
16.0	3.1	2.2	3.6	2.8
20.0	3.2	2.5	3.7	3.0

TABLE A-8 (Continued)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		25 YR EVENT AT FIRST FLOOR		
1.0	1.1	.5	7.8	5.9
2.0	1.2	.6	7.0	5.2
4.0	1.5	.8	5.2	3.8
8.0	2.0	1.2	3.1	2.2
12.0	2.3	1.5	2.9	2.1
16.0	2.5	1.7	2.9	2.2
20.0	2.6	2.0	2.9	2.3
		30 YR EVENT AT FIRST FLOOR		
1.0	.9	.5	7.7	5.7
2.0	1.0	.5	6.6	4.9
4.0	1.2	.7	4.6	3.3
8.0	1.6	1.0	2.6	1.8
12.0	1.9	1.2	2.4	1.7
16.0	2.0	1.4	2.4	1.8
20.0	2.2	1.7	2.4	2.0
		50 YR EVENT AT FIRST FLOOR		
1.0	.5	.3	7.2	5.4
2.0	.6	.3	5.9	4.4
4.0	.7	.4	3.2	2.4
8.0	1.0	.6	1.6	1.1
12.0	1.1	.7	1.4	1.0
16.0	1.2	.8	1.4	1.0
20.0	1.3	.9	1.4	1.1
		100 YR EVENT AT FIRST FLOOR		
1.0	.3	.1	6.8	5.1
2.0	.3	.1	5.0	3.8
4.0	.4	.2	1.8	1.4
8.0	.5	.3	.8	.5
12.0	.5	.3	.7	.5
16.0	.5	.3	.6	.4
20.0	.6	.3	.7	.5

[1]1970 FIA Depth-Damage Data, Skew M, VC/VS = .35.

[2]See "Computational Accuracy", Appendix A for a discussion of the accuracy of these data.

[3]Damage Reduced = Total Damage — Damage with both structure and contents removed (equals zero). The values in the Table are total expected annual damage reduced (structure and contents) expressed as a percentage of structure value. To compute damage reduced in dollars, convert the Table value from percentage to decimal (e.g. 5.0 to .05) and multiply by the value of the structure (e.g. .05 x $35,000. = $1,750.). The value $1,750. is the expected annual damage reduced (structure and contents) for the flood hazard and damageable property assumed in the Table computations.

The damage values tabulated in Tables A-9 through A-13 were computed using 1974 Federal Insurance Administration depth-damage data. They are presented here for the interested reader who may wish to utilize these data in some analysis. Tables A-9 through A-13 are the only place in this report where the damage values are based upon these data. All other tables (and figures) use 1970 Federal Insurance Administration depth-damage data.

TABLE A-9

EXPECTED ANNUAL DAMAGE REDUCED[1,2]
RAISING STRUCTURE THREE FEET[3]

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
2 YR EVENT AT FIRST FLOOR				
1.0	9.4	7.0	14.7	9.9
2.0	9.8	7.5	14.3	10.7
4.0	10.3	7.9	14.0	11.4
8.0	10.0	7.8	12.5	11.1
12.0	9.6	7.6	11.8	10.6
16.0	8.9	7.2	10.1	10.4
20.0	9.5	7.4	12.3	10.9
5 YR EVENT AT FIRST FLOOR				
1.0	4.3	3.1	12.3	8.5
2.0	4.1	3.1	10.5	7.7
4.0	4.2	3.2	8.0	6.5
8.0	4.0	3.1	5.5	4.7
12.0	3.7	3.0	4.7	4.3
16.0	3.4	2.8	4.3	3.9
20.0	3.4	2.8	4.5	4.0
10 YR EVENT AT FIRST FLOOR				
1.0	2.4	1.7	10.8	7.7
2.0	2.0	1.6	6.7	5.8
4.0	2.1	1.6	4.3	3.4
8.0	2.0	1.6	2.8	2.5
12.0	1.7	1.5	2.3	2.1
16.0	1.6	1.4	2.0	1.9
20.0	1.5	1.3	2.0	1.8
15 YR EVENT AT FIRST FLOOR				
1.0	1.8	1.3	10.0	7.3
2.0	1.5	1.1	6.4	4.9
4.0	1.3	1.0	3.0	2.4
8.0	1.3	1.0	1.8	1.6
12.0	1.2	1.0	1.5	1.4
16.0	1.1	1.0	1.3	1.2
20.0	.9	.8	1.2	1.1
20 YR EVENT AT FIRST FLOOR				
	1.4	1.0	9.4	7.0
	1.1	.8	5.4	4.2
	1.0	.8	2.3	1.9
	1.0	.8	1.3	1.2
	1.0	.7	1.1	1.1
	.8	.7	1.0	.9
	[illegible]	.6	.8	.8

TABLE A-9 (Continued)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
25 YR EVENT AT FIRST FLOOR				
1.0	1.1	1.8	9.0	6.6
2.0	.9	.6	4.8	3.8
4.0	.8	.6	1.9	1.5
8.0	.8	.6	1.1	1.0
12.0	.7	.6	.9	.8
16.0	.4	.5	.8	.7
20.0	.5	.5	.6	.6
30 YR EVENT AT FIRST FLOOR				
1.0	1.0	.7	8.6	6.5
2.0	.7	.5	4.3	3.3
4.0	.7	.5	1.6	1.2
8.0	.7	.5	1.0	.8
12.0	.6	.5	.7	.7
16.0	.5	.5	.7	.6
20.0	.5	.4	.6	.6
50 YR EVENT AT FIRST FLOOR				
1.0	.6	.4	7.6	5.8
2.0	.4	.3	3.1	2.5
4.0	.4	.4	1.0	.8
8.0	.4	.3	.6	.5
12.0	.5	.3	.5	.4
16.0	.3	.4	.4	.4
20.0	.3	.3	.4	.3
100 YR EVENT AT FIRST FLOOR				
1.0	.3	.2	6.4	5.0
2.0	.2	.2	1.8	1.5
4.0	.2	.2	.5	.4
8.0	.2	.1	.3	.3
12.0	.2	.1	.2	.3
16.0	.2	.2	.2	.2
20.0	.2	.2	.2	.2

[1]1974 FIA Depth-Damage Data, Skew M, VC/VS = .35.

[2]See "Computational Accuracy", Appendix A for a discussion of the accuracy of these data.

[3]Damage Reduced = Total Damage — Damage with structure (including basement) raised three feet. The values in the Table are total expected annual damage reduced (structure and contents) expressed as a percentage of structure value. To compute damage reduced in dollars, convert the Table value from percentage to decimal (e.g. 5.0 to .05) and multiply by the value of the structure (e.g. .05 x $35,000. = $1,750.). The value $1,750. is the expected annual damage reduced (structure and contents) for the flood hazard and damageable property assumed in the Table computations.

TABLE A-10

EXPECTED ANNUAL DAMAGE REDUCED[1] [2]

RAISING STRUCTURE FIVE FEET[3]

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
2 YR EVENT AT FIRST FLOOR				
1.0	9.4	7.0	17.6	12.3
2.0	10.4	7.9	17.7	13.3
4.0	12.3	9.3	18.0	14.8
8.0	13.3	10.4	17.0	15.0
12.0	12.9	10.4	16.3	14.5
16.0	12.5	8.8	14.5	12.8
20.0	12.6	10.0	16.7	14.7
5 YR EVENT AT FIRST FLOOR				
1.0	4.3	3.1	13.5	9.6
2.0	4.2	3.2	11.7	8.8
4.0	4.9	3.7	9.6	7.8
8.0	5.3	4.1	7.3	6.2
12.0	5.1	4.1	6.5	5.9
16.0	4.7	3.9	6.0	5.4
20.0	4.6	3.8	6.2	5.5
10 YR EVENT AT FIRST FLOOR				
1.0	2.4	1.7	11.4	8.3
2.0	2.1	1.6	8.3	6.3
4.0	2.4	1.8	5.1	4.0
8.0	2.6	2.1	3.7	3.2
12.0	2.5	2.1	3.2	2.9
16.0	2.3	1.5	2.5	2.7
20.0	2.2	1.9	2.8	2.5
15 YR EVENT AT FIRST FLOOR				
1.0	1.8	1.3	10.5	7.7
2.0	1.5	1.1	6.9	5.3
4.0	1.5	1.2	3.5	2.8
8.0	1.7	1.3	2.4	2.1
12.0	1.8	1.4	2.1	2.0
16.0	1.5	.7	1.0	.9
20.0	1.3	1.2	1.7	1.6
20 YR EVENT AT FIRST FLOOR				
1.0	1.4	1.0	9.8	7.3
2.0	1.1	.8	5.8	4.5
4.0	1.2	.9	2.7	2.2
8.0	1.4	1.0	1.8	1.6
12.0	1.4	1.0	2.6	1.5
16.0	1.2	1.1	1.5	1.4
20.0	1.0	.9	1.2	1.2

TABLE A-10 (Continued)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		25 YR EVENT AT FIRST FLOOR		
1.0	1.1	.8	9.3	6.9
2.0	.9	.6	5.1	4.0
4.0	.9	.7	2.2	1.7
8.0	1.0	.8	1.5	1.3
12.0	1.0	.9	1.3	1.2
16.0	.9	.8	1.2	1.1
20.0	.8	.8	.9	.9
		30 YR EVENT AT FIRST FLOOR		
1.0	1.0	.7	8.9	6.7
2.0	.7	.5	4.5	3.5
4.0	.8	.6	1.8	1.4
8.0	.9	.6	1.3	1.0
12.0	.9	.7	1.1	1.0
16.0	.8	.7	1.0	.9
20.0	.7	.7	.9	1.3
		50 YR EVENT AT FIRST FLOOR		
1.0	.6	.4	7.8	5.9
2.0	.4	.3	3.2	2.6
4.0	.5	.4	1.2	.9
8.0	.5	.4	.7	.7
12.0	.6	.5	.6	.6
16.0	.5	.5	.7	.6
20.0	.5	.5	.6	.5
		100 YR EVENT AT FIRST FLOOR		
1.0	.3	.2	6.5	5.1
2.0	.2	.2	1.9	1.6
4.0	.2	.2	.6	.5
8.0	.3	.2	.3	.4
12.0	.3	.2	.3	.3
16.0	.3	.3	.3	.3
20.0	.3	.2	.3	.3

[1]1974 FIA Depth-Damage Data, Skew M, VC/VS = .35.

[2]See "Computational Accuracy", Appendix A for a discussion of the accuracy of these data.

[3]Damage Reduced = Total Damage — Damage with structure (including basement) raised five feet. The values in the Table are total expected annual damage reduced (structure and contents) expressed as a percentage of structure value. To compute damage reduced in dollars, convert the Table value from percentage to decimal (e.g. 5.0 to .05) and multiply by the value of the structure (e.g. .05 x $35,000. = $1,750.). The value $1,750. is the expected annual damage reduced (structure and contents) for the flood hazard and damageable property assumed in the Table computations.

TABLE A-11

EXPECTED ANNUAL DAMAGE REDUCED[1 2]

PROTECTING STRUCTURE THREE FEET[3]

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		2 YR EVENT AT FIRST FLOOR		
1.0	9.4	7.0	17.7	12.4
2.0	9.3	7.1	16.6	11.3
4.0	8.1	6.2	15.1	11.5
8.0	5.6	4.3	10.8	8.4
12.0	4.4	2.7	10.8	8.5
16.0	3.8	3.0	8.5	6.5
20.0	6.3	4.7	11.5	9.0
		5 YR EVENT AT FIRST FLOOR		
1.0	4.3	3.1	13.5	9.6
2.0	3.9	3.0	11.6	8.6
4.0	3.4	2.6	8.6	6.6
8.0	2.4	1.8	5.0	3.8
12.0	1.9	1.4	3.8	3.0
16.0	2.0	1.5	3.6	2.8
20.0	1.9	1.5	3.0	2.1
		10 YR EVENT AT FIRST FLOOR		
1.0	2.4	1.7	11.4	8.3
2.0	2.0	1.5	8.3	6.3
4.0	1.7	1.3	4.6	3.5
8.0	1.2	1.0	2.5	2.0
12.0	.9	.8	1.8	1.5
16.0	.8	.6	1.5	1.2
20.0	.8	.7	1.6	1.2
		15 YR EVENT AT FIRST FLOOR		
1.0	1.8	1.3	10.5	7.7
2.0	1.5	1.1	6.9	5.3
4.0	1.1	.8	3.2	2.5
8.0	.8	.6	1.6	1.3
12.0	.6	.4	1.1	.9
16.0	.5	.4	.9	.7
20.0	.4	.3	.8	.7
		20 YR EVENT AT FIRST FLOOR		
1.0	1.4	1.0	9.8	7.3
2.0	1.1	.8	5.8	4.5
4.0	.9	.6	2.5	2.0
8.0	.6	.5	1.2	1.0
12.0	.5	.3	.8	.7
16.0	.3	.3	.7	.5
20.0	.3	.2	.5	.4

TABLE A-11 (Continued)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		25 YR EVENT AT FIRST FLOOR		
1.0	1.1	.8	9.3	6.9
2.0	.9	.6	5.1	4.0
4.0	.6	.5	2.0	1.5
8.0	.4	.3	1.0	.8
12.0	.3	.3	.7	.6
16.0	.3	.2	.4	.2
20.0	.3	.2	.4	.3
		30 YR EVENT AT FIRST FLOOR		
1.0	1.0	.7	8.9	6.7
2.0	.7	.5	4.5	3.5
4.0	.6	.4	1.7	1.3
8.0	.4	.3	.9	.6
12.0	.3	.2	.5	.5
16.0	.2	.1	.5	.3
20.0	.2	.1	.4	.3
		50 YR EVENT AT FIRST FLOOR		
1.0	.6	.4	7.8	5.9
2.0	.4	.3	3.2	2.6
4.0	.4	.3	1.1	.8
8.0	.2	.2	.5	.4
12.0	.3	.2	.3	.3
16.0	.1	.2	.3	.2
20.0	.2	.1	.2	.1
		100 YR EVENT AT FIRST FLOOR		
1.0	.3	.2	6.5	5.1
2.0	.2	.2	1.9	1.6
4.0	.2	.2	.6	.5
8.0	.1	.1	.2	.2
12.0	.1	.1	.2	.2
16.0	.0	.1	.1	.1
20.0	.1	.1	.1	.1

[1]1974 FIA Depth-Damage Data, Skew M, VC/VS = .35.

[2]See "Computational Accuracy", Appendix A for a discussion of the accuracy of these data.

[3]Damage Reduced = Total Damage — Damage with structure (including basement) protected to three feet above first floor. The values in the Table are total expected annual damage reduced (structure and contents) expressed as a percentage of structure value. To compute damage reduced in dollars, convert the Table value from percentage to decimal (e.g. 5.0 to .05) and multiply by the value of the structure (e.g. .05 x $35,000. = $1,750.). The value $1,750. is the expected annual damage reduced (structure and contents) for the flood hazard and damageable property assumed in the Table computations.

TABLE A-12

EXPECTED ANNUAL DAMAGE REDUCED[1 2]

PROTECTING STRUCTURE FIVE FEET[3]

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		2 YR EVENT AT FIRST FLOOR		
1.0	9.4	7.0	17.7	12.4
2.0	10.3	7.8	18.2	13.7
4.0	11.0	8.4	17.9	14.3
8.0	9.5	7.1	14.5	12.0
12.0	9.2	7.0	13.8	11.6
16.0	8.7	6.6	13.3	11.3
20.0	9.2	6.9	14.5	12.0
		5 YR EVENT AT FIRST FLOOR		
1.0	4.3	3.1	13.5	9.6
2.0	4.2	3.2	11.9	8.9
4.0	4.5	3.4	9.7	7.7
8.0	3.9	2.9	6.5	5.3
12.0	3.5	2.6	5.3	4.5
16.0	3.3	1.8	4.9	4.1
20.0	3.2	2.4	5.1	4.3
		10 YR EVENT AT FIRST FLOOR		
1.0	2.4	1.7	11.4	8.3
2.0	2.1	1.6	8.4	6.4
4.0	2.2	1.7	5.1	4.0
8.0	1.9	1.5	3.3	2.8
12.0	1.5	1.2	2.4	2.0
16.0	1.4	1.1	2.1	1.8
20.0	1.3	1.0	2.1	1.7
		15 YR EVENT AT FIRST FLOOR		
1.0	1.8	1.3	10.5	7.7
2.0	1.5	1.1	6.9	5.3
4.0	1.4	1.1	3.5	2.8
8.0	1.3	1.0	2.1	2.8
12.0	1.1	.8	1.6	1.4
16.0	.9	.7	1.3	1.1
20.0	.7	.6	1.2	1.0
		20 YR EVENT AT FIRST FLOOR		
1.0	1.4	1.0	9.8	7.3
2.0	1.1	.8	5.8	4.5
4.0	1.1	.8	2.7	2.2
8.0	1.0	.8	1.6	1.3
12.0	.9	.6	1.2	1.1
16.0	.6	.5	1.0	.8
20.0	.6	.4	.8	.7

TABLE A-12 (Continued)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		25 YR EVENT AT FIRST FLOOR		
1.0	1.1	.8	9.3	6.9
2.0	.9	.6	5.1	4.0
4.0	.9	.7	2.3	1.8
8.0	.7	.6	1.3	1.1
12.0	.6	.5	1.0	.8
16.0	.5	.4	.8	.6
20.0	.5	.4	.6	.5
		30 YR EVENT AT FIRST FLOOR		
1.0	1.0	.7	8.9	6.7
2.0	.7	.5	4.5	3.5
4.0	.8	.6	1.9	1.5
8.0	.6	.5	1.1	.9
12.0	.5	.4	.8	.6
16.0	.5	.3	.7	.6
20.0	.3	.3	.5	.4
		50 YR EVENT AT FIRST FLOOR		
1.0	.6	.4	7.8	5.9
2.0	.4	.3	3.2	2.6
4.0	.5	.4	1.2	.9
8.0	.4	.3	.7	.6
12.0	.4	.3	.5	.4
16.0	.3	.3	.5	.4
20.0	.3	.2	.3	.3
		100 YR EVENT AT FIRST FLOOR		
1.0	.3	.2	6.5	5.1
2.0	.2	.2	1.9	1.6
4.0	.2	.2	.6	.5
8.0	.3	.2	.4	.4
12.0	.2	.1	.3	.3
16.0	.2	.2	.3	.3
20.0	.2	.2	.2	.2

[1] 1974 FIA Depth-Damage Data, Skew M, VC/VS = .35.

[2] See "Computational Accuracy", Appendix A for a discussion of the accuracy of these data.

[3] Damage Reduced = Total Damage — Damage with structure (including basement) protected to five feet above first floor. The values in the Table are total expected annual damage reduced (structure and contents) expressed as a percentage of structure value. To compute damage reduced in dollars, convert the Table value from percentage to decimal (e.g. 5.0 to .05) and multiply by the value of the structure (e.g. .05 x $35,000. = $1,750.). The value $1,750. is the expected annual damage reduced (structure and contents) for the flood hazard and damageable property assumed in the Table computations.

TABLE A-13

EXPECTED ANNUAL DAMAGE REDUCED[1 2]

REMOVING STRUCTURE AND CONTENTS FROM FLOOD HAZARD AREA[3]

(Equivalent to Total Damage)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		2 YR EVENT AT FIRST FLOOR		
1.0	9.4	7.0	17.7	12.4
2.0	10.4	7.9	18.3	13.8
4.0	13.2	10.0	20.2	16.4
8.0	17.6	13.7	23.1	20.2
12.0	19.4	15.7	24.7	22.1
16.0	20.6	17.1	26.2	23.8
20.0	19.5	16.0	25.6	22.9
		5 YR EVENT AT FIRST FLOOR		
1.0	4.3	3.1	13.5	9.6
2.0	4.2	3.2	11.9	8.9
4.0	5.2	3.9	10.4	8.4
8.0	6.9	5.3	9.6	8.2
12.0	8.0	6.5	10.2	9.2
16.0	8.5	7.2	10.6	9.7
20.0	8.4	7.2	10.8	9.2
		10 YR EVENT AT FIRST FLOOR		
1.0	2.4	1.7	11.4	8.3
2.0	2.1	1.6	8.4	6.4
4.0	2.5	1.9	5.4	4.3
8.0	3.4	2.7	4.8	4.2
12.0	4.1	3.4	5.2	4.7
16.0	4.6	4.0	5.6	5.2
20.0	4.7	4.2	5.8	5.4
		15 YR EVENT AT FIRST FLOOR		
1.0	1.8	1.3	10.5	7.7
2.0	1.5	1.1	6.9	5.3
4.0	1.6	1.2	3.7	3.0
8.0	2.2	1.7	3.1	2.7
12.0	2.8	2.2	3.4	3.1
16.0	3.1	2.7	3.7	3.4
20.0	3.2	2.9	3.9	3.7
		20 YR EVENT AT FIRST FLOOR		
1.0	1.4	1.0	9.8	7.3
2.0	1.1	.8	5.8	4.5
4.0	1.2	.9	2.8	2.3
8.0	1.7	1.3	2.3	2.0
12.0	2.1	1.6	2.5	2.3
16.0	2.3	2.0	2.8	2.6
20.0	2.5	2.2	2.9	2.8

TABLE A-13 (Continued)

Flood Hazard Factor (FHF)	One Story No Basement (1SNB)	Two Story No Basement (2SNB)	One Story With Basement (1SWB)	Two Story With Basement (2SWB)
		25 YR EVENT AT FIRST FLOOR		
1.0	1.1	.8	9.3	6.9
2.0	.9	.6	5.1	4.0
4.0	.9	.7	2.3	1.8
8.0	1.3	1.0	1.9	1.6
12.0	1.6	1.3	2.0	1.8
16.0	1.8	1.5	2.2	2.0
20.0	2.0	1.8	2.3	2.2
		30 YR EVENT AT FIRST FLOOR		
1.0	1.0	.7	8.9	6.7
2.0	.7	.5	4.5	3.5
4.0	.8	.6	1.9	1.5
8.0	1.1	.8	1.6	1.3
12.0	1.3	1.0	1.6	1.5
16.0	1.5	1.2	1.8	1.6
20.0	1.7	1.5	2.0	1.9
		50 YR EVENT AT FIRST FLOOR		
1.0	.6	.4	7.8	5.9
2.0	.4	.3	3.2	2.6
4.0	.5	.4	1.2	.9
8.0	.6	.5	.9	.8
12.0	.8	.6	.9	.8
16.0	.8	.7	1.0	.9
20.0	1.0	.8	1.1	1.0
		100 YR EVENT AT FIRST FLOOR		
1.0	.3	.2	6.5	5.1
2.0	.2	.2	1.9	1.6
4.0	.2	.2	.6	.5
8.0	.3	.2	.4	.4
12.0	.3	.2	.4	.4
16.0	.3	.3	.4	.4
20.0	.4	.3	.4	.4

[1]1974 FIA Depth-Damage Data, Skew M, VC/VS = .35.

[2]See "Computational Accuracy", Appendix A for a discussion of the accuracy of these data.

[3]Damage Reduced = Total Damage — Damage with both structure and contents removed (equals zero). The values in the Table are total expected annual damage reduced (structure and contents) expressed as a percentage of structure value. To compute damage reduced in dollars, convert the Table value from percentage to decimal (e.g. 5.0 to .05) and multiply by the value of the structure (e.g. .05 x $35,000. = $1,750.). The value $1,750. is the expected annual damage reduced (structure and contents) for the flood hazard and damageable property assumed in the Table computations.

APPENDIX B

ENGINEER'S COST ESTIMATES[1]

In estimating costs of modifying existing sites and structures it must be recognized that each site and structure is probably unique. Rare will be the case where several structures in one location will be the same size, constructed of the same materials and be surrounded by similar site conditions. For this study a "standardized" structure and site is used for the purpose of quantifying construction components. Costs for each component are estimated assuming each structure and site modified is an individual "project." Therefore, it has been assumed that there will be little savings due to economies of scale in labor and materials. Economies of scale are applicable only when many similar structures or sites are constructed or modified under a single construction contract, i.e., a new residential subdivision or a continuous "ring" levee that protects several structures. In specific project areas where economies of scale can be applied, unit costs presented herein should be adjusted downward accordingly.

Estimated unit costs for new construction or structure or site modification are presented on the basis of "unit cost per gross square foot of structure." In a single family, detached residence, this gross area would include the roof area covering the house (and garage, if attached). This was determined to be the most useful common denominator for the vast array of possible structure configurations and types. Furthermore, the gross square footage of existing structures can be readily ascertained from aerial photographs thus minimizing the need for field reconnaissance and measurements in preliminary studies.

The "standard" structure used for preparing the unit cost estimates is a one-story, single family residence having a gross area of 1,600 square feet. The standard configuration includes an attached 2-car garage, raised concrete perimeter foundation with interior piers and posts, concrete driveway, small patio and porch, all on a lot 60 feet wide and 120 feet deep and served by community utilities such as sewer, water, storm drainage, gas, telephone and electric power. Separate unit cost estimates are made for modification of typical optional items such as fireplace, fencing, basement, second story, septic tank, domestic well, etc. Cost estimates include allowance for common conditions regarding site soils and landscaping, age and integrity of the structure, construction materials, etc. Special and unique conditions must be accounted for separately.

Unit costs used for construction materials assume a nominal contractor's discount on small quantities. Labor costs are based on union-scale. In geographic areas with non-union or depressed labor costs, proportionate downward adjustments should be made when applying unit costs. Allowances have been included to cover contractor's overhead, profit, start-up costs, and also the costs of architectural/engineering planning and design. Costs are derived on a 1976 construction year base and should be adjusted upward annually in proportion to accepted national escalator indices such as the Engineering News Record (ENR) and Lee Saylor Inc. (LSI) indices. California labor and materials costs are assumed as base and geographic adjustments should be appropriately applied.

[1] The cost estimates discussed in this Appendix were prepared by Justice & Associates, Consulting Engineers, Sacramento, California.

The source of unit construction and materials cost estimates is varied. Recently published construction estimator's guidelines, first-hand knowledge of cost consultants, and interview with specialty contractors are all incorporated and appropriately weighted. Quantity and cost estimates are based on typical construction practices which would consider optimum sequence of construction, minimum physical obstructions, appropriate construction season and timely prosecution of the work.

Data presented in this Appendix is a summary of the more detailed estimates which were made. These data are shown in Tables B-1 through B-7 and include,

- Temporary Closures and Exterior Sealants
- Raising an Existing Structure
- Small Walls and Levees
- Removing an Existing Structure
- Demolition of an Existing Structure
- Restoration of an Existing Site After Structure Removal
- New Site Preparation for Existing Structure

While cost estimates are shown for a variety of items for each measure only those which were considered base items — items necessary for use of the measure — were used in the Chapter. This was done because it was desired to compare expected annual damage with a cost which was a minimum, that is, the lower bound of the cost range. By comparing a minimum cost with an optimistic damage a upper bound of economic feasibility could be established.

TABLE B-1

SUMMARY OF ENGINEER'S COST ESTIMATE TEMPORARY CLOSURES AND EXTERIOR SEALANTS

Item	First Cost	Cost per Gross Square Foot of Floor Area
SEAL WALLS	$2,126	$1.34
• Remove shrubs, excavate and replace soil, sandblast wall, caulk and seal wall, repaint wall.		
SEAL FLOORS	3,761	2.35
• Remove and replace floor covering, clean slab, caulk and seal joints, seal slab.		
SEWER VALVE	375	0.23
• Installed		
SUMP PUMP	813	0.51
• Sump, pump, generator		
TEMPORARY CLOSURES	1,123	0.70
• Aluminum shield closures, front door and garage entrance door, construct wall separating garage and house, seal and paint wall.		
CONSTRUCT WALL AROUND PATIO	1,413	0.88
• Masonry wall, caulk and seal wall, gate, drain inlet and pipe to sump.		
SEAL FIREPLACE	433	0.27
• Construct wall around base, seal fireplaces.		
WATERPROOF DOMESTIC WELL	420	0.26
• Extend steel casing, remove and replace pump piping, modify housing, wiring.		
WATERSEAL LOWER WINDOWS	938	0.60
• Three 3'x4' windows, brick, caulk, seal.		

TABLE B-2

SUMMARY OF ENGINEER'S COST ESTIMATE
RAISING AN EXISTING STRUCTURE[1]

Item	First Cost	Cost per Gross Square Foot of Floor Area
BRACE AND LOAD STRUCTURE	$3,200	$2.00
• Brace and load structure, disconnect and reconnect utilities		
FOUNDATION RECONSTRUCTION		
• Alternative 1: place and compact fill, construct new foundation, place erosion protection, reset structure.	5,760	3.60
• Alternative 2: extend existing foundation, extend walls and piers, reset structure, add veneer front only.	3,312	2.07
• Alternative 3: construct new foundation walls and piers, remove and dispose of existing foundation, reset structure.	4,464	2.79
RELANDSCAPE	595	0.37
• Front, side and rear yards.		
REMOVE AND DISPOSE OF PORCHES, STAIRS, DRIVEWAY, WALKS	528	0.33
RECONSTRUCT PORCHES, STAIRS, DRIVEWAY, WALKS	1,456	0.91
ADJUST BASEMENT TO GRADE	500	0.31
STRUCTURE ADJUSTMENTS		
• Additional bracing (stucco)	300	0.23
• Remove brick veneer	420	0.33
• Deteriorated structure	192	0.12
• Reconstruct chimney	880	0.55
• Update structure to Code (electrical, plumbing)	1,760	1.10

[1] Estimates assumed structure is being raised 3 feet.

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TABLE B-3

SUMMARY OF ENGINEER'S COST ESTIMATE
SMALL WALLS AND LEVEES[1]

Item	First Cost 3 Ft	First Cost 5 Ft	Cost per Gross Square Foot of Floor Area 3 Ft	Cost per Gross Square Foot of Floor Area 5 Ft
LEVEE				
• Import and compact levee fill	$1,519	$3,370	$0.50	$1.00
• Relandscape	1,200	1,200	0.75	0.75
• Remove and replace concrete driveway and walk	3,441	3,441	2.15	2.15
• Modify interior drainage, install sump pump	1,521	1,521	0.95	0.95
• Sewer anti-backflow value	375	375	0.23	0.23
• Levee erosion protection	459	960	0.29	0.60
WALL				
• Trench, place reinforcing and concrete for footing, place masonry wall	2,992	4,976	1.87	3.11
• Brick veneer, one side only	1,648	2,352	1.03	1.47
• Relandscape	624	624	0.39	0.39
• Regrade lot for drainage and add sump pump	1,438	1,438	0.90	0.90
• Sewer anti-backflow value	375	375	0.23	0.23
• Seepage control (underdrain)	1,143	1,143	0.71	0.71

[1] Levee and wall for backyard only: levee length 216 feet
wall length 140 feet

TABLE B-4

SUMMARY OF ENGINEER'S COST ESTIMATE REMOVING AN EXISTING STRUCTURE[1]

Item	First Co	Cost per Gross Square Foot of Floor Area
BRACE, LOAD, MOVE STRUCTURE	$3,200	$2.00
• Includes disconnect, reconnect utilities, and moving up to 15 miles.		
STRUCTURE CONDITION	192	0.12
• Additional bracing for structures in poor condition.		
UPDATE TO CODE	1,760	1.10
• Electrical and plumbing		
HAUL OVER 15 MILES	1,280	0.80
PARTITION STRUCTURE	320	0.20
• Cut structure to make separate hauls.		
STRUCTURE FACING		
• Stucco: additional bracing and loading	320	0.20
• Brick veneer: remove veneer	416	0.26

[1] Cost estimates were made assuming a frame structure on raised (18") foundation.

TABLE B-5

SUMMARY OF ENGINEER'S COST ESTIMATE DEMOLITION OF AN EXISTING STRUCTURE

Item	First Cost	Cost per Gross Square Foot of Floor Area
STRUCTURE DEMOLITION AND DISPOSAL	$2,080	$1.30
• Frame building, no hazards, normal access		
REMOVE AND DISPOSE		
• Concrete flat work	495	0.31
• Concrete wall and pier foundation	1,042	0.65
• Slab-on-grade foundation	720	0.45
• Underground utilities	206	0.13
• Chimney and fireplace	175	0.11
REGRADE AND RESTORE SITE	1,260	0.79
• Clear and grub brush & stumps, replant grass		
BACKFILL		
• Basement	450	0.28
• Septic tank	333	0.21
• Abandon well	250	0.16
• Swimming pool	1,025	0.64

TABLE B-6

SUMMARY OF ENGINEER'S COST ESTIMATE
RESTORATION OF AN EXISTING SITE AFTER STRUCTURE REMOVAL

Item	First Cost	Cost Per Gross Square Foot of Floor Area
ABANDON UTILITIES	$ 200	$0.13
• Close service on water, sewer, gas, telephone		
REMOVE UNDERGROUND UTILITIES	206	0.13
REMOVE AND DISPOSE		
• Concrete flatwork (sidewalk, driveway, patios)	495	0.31
• Structure foundation	1,042	0.65
• Fireplace chimney	175	0.11
• Pool or patio concrete	360	0.23
BACKFILL		
• Basement	450	0.28
• Swimming pool	1,025	0.64
REGRADE AND RESTORE SITE	1,250	0.78

TABLE B-7

SUMMARY OF ENGINEER'S COST ESTIMATE
NEW SITE PREPARATION FOR EXISTING STRUCTURE

Item	First Cost	Cost per Gross Square Foot of Floor Area
GRADE LOT AND COMPACT PAD	$1,530	$0.96
• Clear and grub, site grading		
CONSTRUCT FOUNDATION	1,560	0.98
• Wall and pier foundation		
CONCRETE FLAT WORK	1,031	0.64
• Driveway, walks, steps		
UTILITY HOOKUP	2,257	1.41
• Sewer, water, gas, electrical		
LANDSCAPING	588	0.37
• Lawn, trees, shrubs		
OFFSITE IMPROVEMENTS	2,500	1.60
• Streets, gas and sewer, storm drain, water, street lights, electrical, telephone		
FENCING	424	0.26
FIREPLACE	886	0.55
BASEMENT CONSTRUCTION	2,863	1.80
• Excavation, wall and floor construction		
SEPTIC TANK WITH LEACH LINES	1,263	0.80
WELL FOR POTABLE WATER	5,000	3.13
• Pump, pressure tank, steel cased		

APPENDIX C

PREPAREDNESS PLANNING

This Appendix expands the material in Chapter 8, Flood Forecast, Warning and Evacuation and discusses in detail the principal components of a preparedness strategy. These include:

- Flood Threat Recognition Methods
- Procedures for Flood Warning
- Evacuation of Persons and Property
- Implementation of Temporary Protective Measures
- Maintenance and Management of Vital Services
- Post-Flood Reoccupation and Recovery

Detailed information is also presented on the applicability of these actions to specific flood and community conditions. Cost information was not available for all components, however, engineer's cost estimates are included for some and cost items identified for the remainder.

Flood Threat Recognition Methods

The capability to recognize a potential flood threat early is an integral part of an effective flood preparedness plan. Techniques for recognizing potential flood threats vary from sophisticated forecasting models and automated gaging and communication equipment to visual inspection of streams by volunteer observers. The National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA) is responsible for preparing forecasts and issuing flood warnings throughout the United States, except in the Tennessee River Basin where NWS shares this responsibility with the Tennessee Valley Authority. The NWS routinely issues river stage forecasts for 1700 locations throughout the country. Floods are categorized by the NWS as two types: those that crest in six hours or more and those that crest more quickly. The latter type is designated as "flash floods" (1).

NWS Flood Forecasting Methods of Major Streams Systems - The NWS has 13 River Forecasting Centers located throughout the United States. There are an additional 82 River District Offices within the major river watersheds. Based on flood forecasts transmitted to the River District Offices, forecasts and warnings are transmitted by the NOAA National Weather Wire Service and the NOAA VHF/FM Radio Transmission Service to organizations with receiving equipment. Organizations without receiving equipment are notified by telephone or telegraph (1).

These NWS forecasts are generally effective only on major stream systems with predictions of flood stages made every 12 to 24 hours during a flood threat. The forecasts include predicted flood stages for three to five days in advance and include the predicted flood crest stage and time of the flood crest. Recorded precipitation and stream data (mostly observed) along with anticipated precipitation are used in developing flood predictions in the 13 Forecasting Centers of the NWS.

The NWS Forecasting Centers at Slidel, Louisiana; Portland, Oregon; and Sacramento, California, have telemetry monitoring capability of some regional precipitation and stream gages. This expedites data collection, and therefore, shortens the forecasting period for the watersheds where the telemetry capability is available.

Although some NWS Forecasting Centers have made significant progress in flood forecasting the current NWS system has four major shortcomings on a national basis (1). These shortcomings are:

- The National Weather Wire Service is not available in all states (not presently available in 12 states).
- Many smaller communities and broadcasting stations do not pay the $100 per month for the wire service.
- Disseminations of forecasts or warnings via telephone or telegraph is time consuming and slow.
- None of the forecasts or warnings reach the public directly; the press, radio and television must interpret and relay the messages.

Flash Flood Recognition Methods - The NWS forecasting system is generally effective on major stream systems but is unsuitable for streams of a flash flood nature due to the time required to determine the forecasts, and limited data availability. Therefore, additional means of flood threat recognition are required for these streams. Current estimates are that approximately 2500 communities are flash flood prone. The methods of recognizing a flood threat for areas subjected to flash flood conditions include (2):

a. **Self-Contained Community or County Forecasting Systems -** A forecasting system may be implemented on a community or preferably county level which uses telemetry capability to monitor precipitation and stream gages and a mini computer for calculations of stream forecasts. The requirements are 3 or 4 precipitation gages already distributed at desired locations and a minimum of one stream gage. The equipment may be compact, relatively cheap and effective. However, the self-contained forecasting systems require knowledge of the forecasting process and equipment, they must be manned continuously during a potential flood threat, and require continuous maintenance of equipment. *Figure C-1 CONCEPTS OF A* FLOOD FORECASTING AND WARNING PROCESS, conceptually illustrates this process.

b. **Automatic Flash Flood Alarm Systems -** The automatic flash flood alarm system is used to activate an alarm or warning when the stream reaches a predetermined danger or "alert"stage. These systems are typically designed to monitor stream gages with an alarm being activated automatically. The alarm may be a siren to warn the flood threatened areas of a community or may be a signal, such as a flashing light, in a police or fire station. Figure C-2 TYPICAL INSTALLATION OF FLASH FLOOD ALARM SYSTEM illustrates a typical installation of an automatic flash flood alarm on a bridge.

c. **NWS Forecasting Charts -** For areas where other forecasting techniques are not applicable, the NWS may provide the community with simplified forecasting charts to be used by a responsible official to make flood forecasts. This method is relatively easy to learn, economical and with the assistance of the NWS, relatively reliable for many situations.

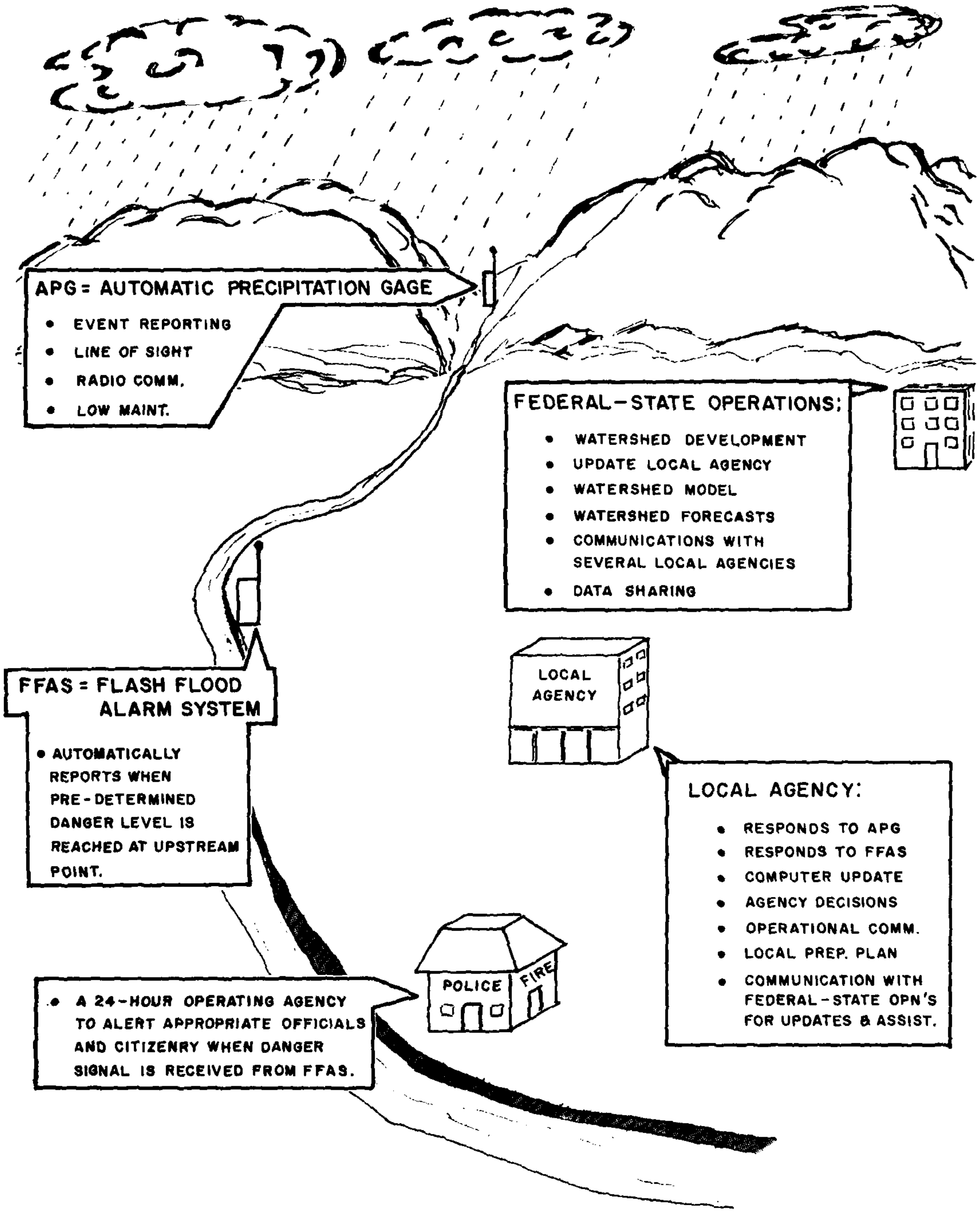

Figure C-1. Concepts of a Flood Forecasting and Warning Process. (Reference 2)

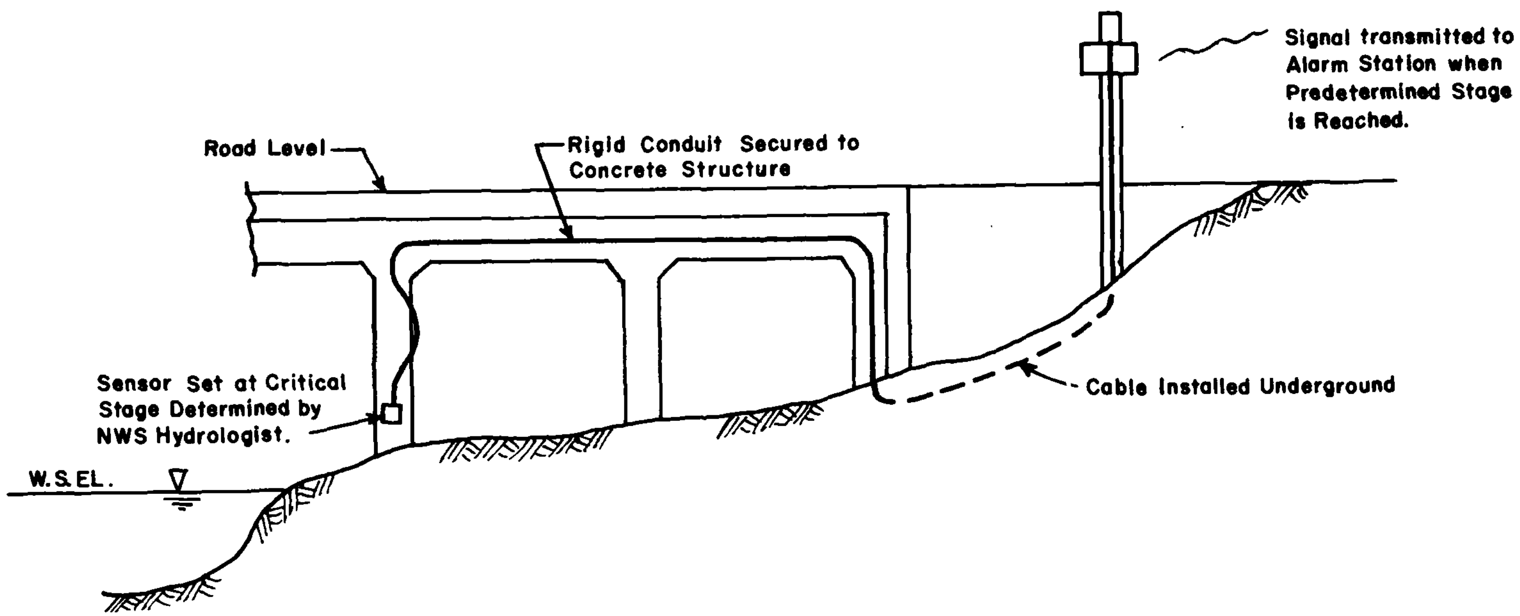

Figure C-2. Typical Installation of Flash Flood Alarm System. (3)

d. **Weather Warning Broadcasts** - The conventional weather warning bulletin which usually is broadcasted over mass media is used in many potential flash flood areas. The accuracy of the warning depends on the expertise of the local weather forecaster who issued a generalized warning of possible flood conditions.

e. **Manual Observations** - The use of trained observers to watch streams or precipitation gages of watersheds with a flash flood nature may be an important part of a perparedness plan where other methods are economically or otherwise not feasible. Observers may be local officials, police or firemen or other responsible citizens. The use of trained observers requires that surveillance capabiiity be maintained 24 hours a day.

Procedures for Flood Warning

One of the primary objectives of flood preparedness planning is to assist local officials or decision makers in determining the most effective means of dissemination of flood warnings, i.e., when to issue a warning, how to disseminate the warning in a manner that will reach the entire populace, and for the content of the warning to be sufficient to motivate the community to respond so that a minimum amount of flood loss occurs. Since the amount of warning time is critical to the overall effectiveness of reducing flood losses and in some cases the loss of lives, it is imperative that the above aspects of flood warning dissemination be considered prior to an actual flood crisis situation. The timeliness and reliability of the decision to warn of an impending flood is critical to the successful functioning of a preparedness plan. The time element on major streams is less critical because normally the preparedness plan would be designed to be implemented in stages so that actions could be taken progressively and opportunity to improve the forecast increases as more data becomes available. The decision time for flash flood streams is critical to actions required to temporarily evacuate life and property. It is therefore important that warning decisions be made by competent agencies or officials. False alarms are expensive, reduce the overall credibility of officials and can lead to a negative effect on the response to future flooding.

The basic process involved in developing an effective flood warning system is illustrated in Figure C-3 WARNING DISSEMINATION PROCESS, and includes:

- Warning decision process
  - Must be made by responsible official or agency if possible.
  - Knowledge of current and projected flood threat.
  - Decision time influenced by nature of physical stream system and threat: Major drainage system; flash floods; potential structural failure.
- Warning disseminations must reach entire threatened community (including the handicapped), isolated and remote areas, etc. The issuance of a flood warning must be made with consideration of specific location of people and not to the people in general.
- The type of warning used must account for the nature of the community at the time of the threat.
  - Weekday: Many people at work, school, at home.
  - Night: People at home, asleep.
  - Weekend and holidays: People at home, recreation.

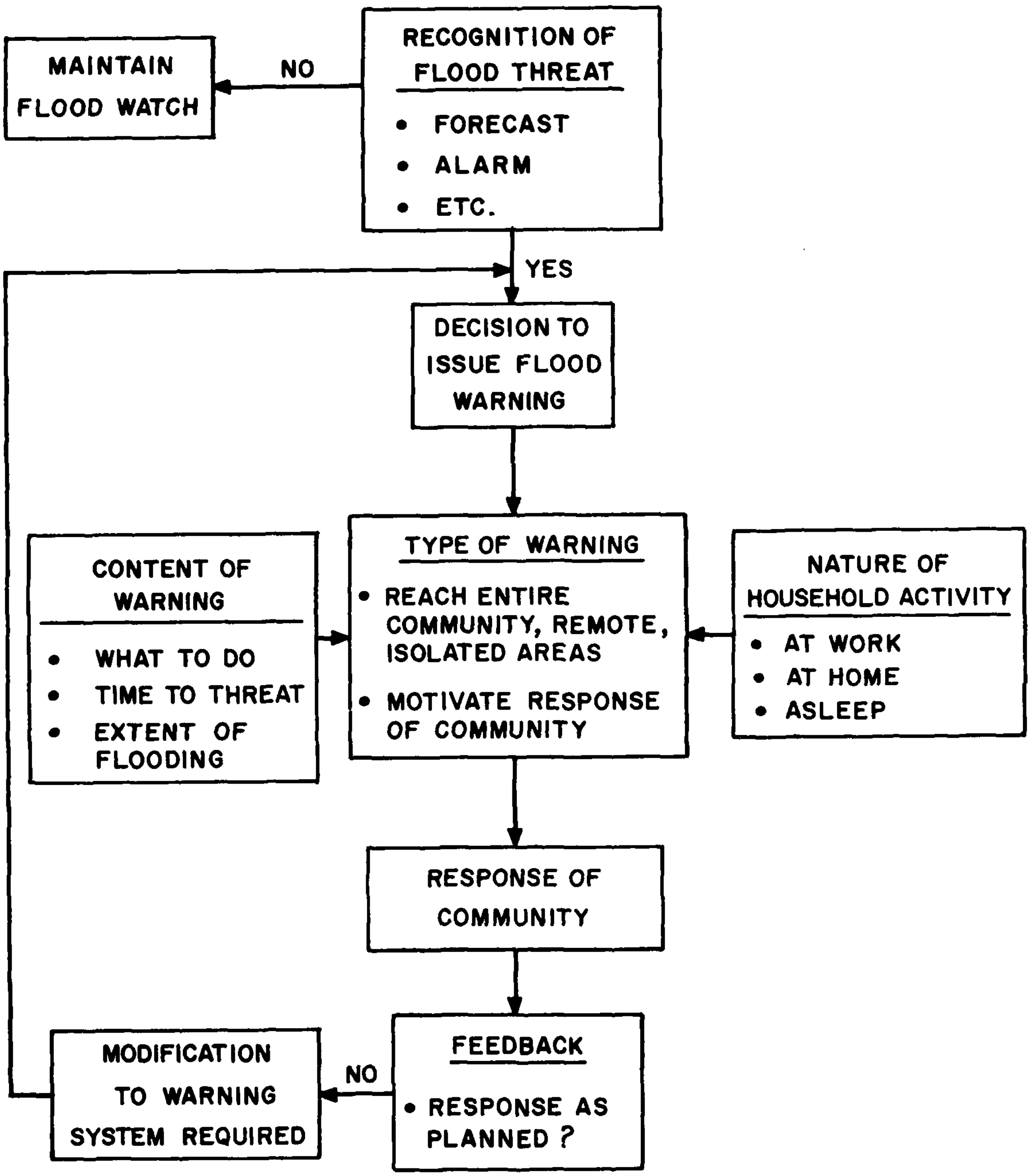

Figure C-3. Warning Dissemination Process

- Methods of communication or dissemination of flood warnings.
  - Radio: Probably best mass media system since almost everyone has a transistor or car radio which may be used during power failure.
  - Television: May reach large number of people, but subjected to power failure.
  - Sirens: May reach large masses but may be difficult to distinguish between other warnings such as tornado.
  - Telephone: Can be effective but highly subjective to line failure during severe storms.
  - Door to Door: Most effective warning system and necessary for many flood conditions to assure everyone has received notice of the flood threat.
  - Public Address Systems: May be effective in disseminating warnings quickly to groups of people, lot and blocks, buildings, remote areas, etc.
- The content of the warning is very important to motivate the community to respond effectively. It is also necessary to continuously repeat the warning to provoke the populace to respond. The content of the warning message should include:
  - Allowable time for evacuation; minutes, hours, days.
  - If known, the relationship of the predicted flood crest to familiar landmarks or recent historic flood events.
  - A description of the appropriate course of action; where to go, what route, etc.
- The person who issues the warning has a bearing on its credibility and the corresponding response of the people. For mass media warnings, a known local official, such as the mayor, should be responsible. Local officials, such as policemen or firemen, should issue door to door warnings if possible. Where large masses of people are threatened the use of the existing infrastructure of the community (such as businesses, churches, schools and other social organizations) is probably the most credible, quickest and most effective means of issuing a flood warning.
- Feedback as to the effectiveness of the warning and response of the community is important to assure the system is functioning as desired. If the feedback indicates the system is malfunctioning then immediate modifications and different types of warning may be required.

In many cases sufficient existing social and physical means of warning are available to develop an efficient warning system. Flood preparedness planning should be designed to organize and develop these resources into a system that will enable the maximum warning time possible and to motivate the community to respond in an effective manner. The response of people to the available warning time may be generalized as follows:

- Less than 6 hours (flash flood conditions). Prevent loss of life with a minimum reduction in property damage by elevating contents, or removal of certain items such as automobiles, etc.
- 6 - 24 hours of warning time. May permit evacuation of some contents and a limited amount of temporary protection, the shutting off of utilities, etc.
- Greater than 24 hours. Permits removal of many of the contents, the installation of temporary flood proofing measures and the implementation of flood fighting measures.

Evacuation of Persons and Property

The primary and initial concern involved with any flood situation is the successful evacuation of endangered people from the threatened areas. This is especially true of streams of a flash flood nature. Much of the emphasis of successful evacuation and response is placed upon the warning system.

The warning must be recognized and interpreted by the threatened people in a manner that motivates them to respond so that they are safely evacuated prior to the time the flood reaches dangerous depths. This requires that the content of the warning message itself contain specific instructions as to the safe evacuation routes and temporary stations of safety and shelter.

People respond to warnings in different ways, some may react immediately while others may either disbelieve the warning or are reluctant to leave until it is too late for effective rescue procedures. The necessity of rescuing people who did not receive warning is of considerable concern in isolated areas along flash flood streams. Factors that motivate threatened people to respond to a flood warning are:

- Repeated reception of a warning.
- Visual recognition of a flood threat (rainfall, rising streams).
- Reception of a warning from a known public official, the mayor, policeman, etc., or from a relative or person well known, such as a neighbor, member of a community organization, or business associate.
- The time elapsed since a past flood event; if a flood has occurred within the memory of a person, the response is usually more positive.
- Recognition of other people evacuating the area.

The preparedness plan may include the following considerations with regard to a successful evacuation of residences (4):

- Establishment of rescue squads, medical, fire, and other assistance requirements to search for stranded survivors and attend to other emergencies.
- Identification of rescue and emergency equipment which may be utilized during a flood event; trucks, boats, helicopters, life jackets, fire equipment, etc.
- Development of priorities of evacuation based on the time and depth of flooding and the availability of escape and rescue routes or methods.
- Determination of evacuation routes which are safe, adequate to handle the expected traffic and are known by the people being evacuated. Traffic control may be required to expedite the evacuation.
- The destinations of the evacuated people should be known, reachable within the amount of warning time and safe from flooding, severe weather or other dangers. If the duration of the flood is substantial, or the flooded residences unoccupiable for a prolonged period after the flood, provisions of food and shelter may be required. Schools, churches, public buildings often provide the best locations for temporary assistance, shelter, and quarters if large numbers of people are involved.
- Provide assistance in transporting people from the threatened areas, trucks, automobiles, etc.

- Provide surveillance of the evacuated or to insure safety and protection of property. This may be provided by the local police, Sheriff's office, National Guard Units, etc.

An objective of a flood preparedness plan is the reduction of flood losses by elevation or evacuating movable property prior to the occurrence of the flood event. The effectiveness of reducing flood losses by elevating or evacuating movable property is dependent upon:

- The early response of the populace to a flood warning.
- The amount of warning time.
- Depth of flooding.
- Type of structure; basement, two stories, mobile home, etc.
- Type of movable property; residential contents, industrial machinery, commercial merchandise, etc.
- The availability of manpower and equipment; trucks, moving vans, vans, etc.
- The availability of storage space during prolonged flood durations or rehabilitation of structures.

The elevation of movable property includes the moving of contents from basements to first floors, first floors to second floors, placing of contents on tables, countertops, etc. For situations involving limited warning time only the more valuable, easily moved items may be elevated due to time and manpower constraints. For flood conditions where sufficient warning time is available and where elevation of contents are not feasible because of the depth of flooding evacuation of movable property may result in significant flood loss reduction. Evacuation of movable property may include; furnishings, clothing, personal valuables (papers, jewelry), files, finished products, machinery, automobiles, trucks, mobile homes, etc. The success of the evacuation of contents is based upon sufficient warning time and the availability of manpower and equipment (trucks, moving vans, etc.) to perform the evacuation. For conditions where flooding is of substantial duration or post flood reoccupation of the structure is not immediately feasible, safe storage locations of the evacuated items is required.

If possible, the flood warning aspect of the preparedness plan must include information as to the amount of time available for evacuation of contents, the projected flood crest, and the appropriate action to be taken. For streams of a flash flood nature, public awareness programs may be the most effective means of minimizing content damages by indicating the best means of elevating and evacuating the most valuable contents in a short period of time. For floods involving streams where more warning time is available the preparedness plan may include provisions for assistance (manpower and equipment) of evacuating movable property and safe locations of storage of the property until reoccupation can occur. The plan may also identify the appropriate evacuation routes and make provisions for traffic control, closing of sewers, shutting off of utilities, etc.

Implementation of Temporary Protective Measures

This component of a preparedness plan includes temporary flood proofing of structures (residences, businesses, industries, etc.) and the more comprehensive aspect of flood fighting by installation of flood barriers, pumping, etc. The temporary flood proofing of structures is performed on an individual structural basis and includes:

- Closing of openings and perhaps the structure itself by using plywood, polyethylene sheets, sandbags, etc.
- The use of pumps to remove interior waters.

A preparedness plan may include the following information associated with temporary flood proofing of structures:

- Identification of types and locations of structures where temporary flood proofing is applicable.
- The source and location of materials that may be used to flood proof.
- The availability and distribution of the materials.
- The estimated time required to temporary flood proof a structure compared to the amount of warning time.

Flood fighting incorporates a broad range of damage reduction procedures that can be implemented and may significantly reduce flood losses if forecasts of time to crest and crest elevations are accurate and sufficient warning time is available. These procedures include:

- Raising the protection level of existing protection works such as levees or floodwalls by installation of sandbags, flashboard, etc.
- Closures of railroad, street, highway openings in existing protection works.
- Protection of backwater entry through manholes, sewers, etc., by ringing the openings with sandbags, etc.
- Construction of barriers using sandbags, flashboard, earth, sand, etc., which prohibits the entry of the floodwaters into a damageable area.
- The use of pumps to remove sewage, interior runoff or backwater, seepage drains, etc.
- Protection of erosion of levees, temporary flood barriers, bridges, etc., by using riprap, reinforcement of embankments, snow fence, etc.

The preparedness plan may include the following items associated with flood fighting:

- Identification of areas where flood fighting measures are feasible, including information itemizing the course of action that should be taken at specific river stages, such as, levee closures, manhole protection, sewer closures, etc.
- Identification of location, type, and availability of flood fighting equipment.
  - Storage locations of sandbags, pumps, generators, etc.
  - Availability of heavy equipment, bulldozers, trucks, etc.
  - Others.
- Identification of possible flood fighting assistance personnel: Schools, businesses, National Guard Units, Corps of Engineers, etc.
- Traffic and pedestrian control measures.

Maintenance and Management of Vital Services

The capability to maintain vital services may be of extreme importance during a flood crisis. Vital services include power, sewage, water, traffic routes, as well as hospitals, emergency

equipment, public and private records, etc. The preparedness plan must specifically identify how these services will be maintained and managed. The local utilities obviously play a vital role in this important component of preparedness planning.

Post-Flood Reoccupation and Recovery

Once the flood has receded, reoccupation and recovery of the community or area begins. This phase of a flood disaster includes:

- Supplies or allowance for public health: Disease, insect and pest control; water and sewage sources, medical assistance, etc.
- Return of other vital services.
- Repair of damaged structures and other items.
- Removal of sediment, debris, flood fighting equipment and materials.

The preparedness plan may identify how the above phases of post-flood reoccupation and recovery should be performed. A listing of available assistance, both State and Federal agencies, may be included in the plan.

Applicability of Preparedness Planning

The wide variety of components and measures available for preparedness planning affords the opportunity to tailor a plan to local community conditions. Some actions are appropriate to some conditions, some to others. Table C-1 outlines important considerations for evaluating the applicability of these actions.

TABLE C-1

APPLICABILITY OF PREPAREDNESS PLANNING MEASURES

Plan Component	Applicability
1. Recognition of a Flood Threat A. Establishment of a county or community data collection system in conjunction with a NWS Forecasting Center for obtaining flood forecasts.	• Applicable for communities or systems located on major streams systems where forecast periods are effective. • If system incorporates telemetry capability for data collection networks, the system is presently applicable only for NWS Forecasting Centers at Portland, Oregon; Slidel, Louisiana, and Sacramento, California. Future installations could expand this capability. • Feasible only for communities which maintain 24 hour forecasting service.
B. Self contained-community or county forecasting office with telemetry capabilities on stream and precipitation gages.	• Applicable for flash flood streams. • High initial and continuous costs are prohibitive for many counties or communities. • Responsible personnel must man office 24 hours per day during flood seasons.
C. Installation of automatic flash flood alarm systems activated at a predetermined stream stage.	• Applicable for flash flood prone communities. • Economical to install and maintain. • Most effective when located upstream of community where rising limb of flood hydrograph can provide advanced warning of threat. • Alarm must be activated in office manned 24 hours per day; police or fire station.
D. NWS simplified forecasting charts.	• Applicable to flash flood streams where other forecasting systems are not feasible. • Economical and easy to interpret. • Estimating the hydrologic response characteristics of a stream from charts may result in significant errors in timing, magnitude and stage of the flood wave.
E. Organized and trained observers of gages and streams.	• Applicable for nonrecording or recording gages without telemetry capability.

- May not be effective since people are sometimes reluctant to make observations at night or during severe weather.

2. Warning Systems

A. Sirens	• Generally applicable to flash flood conditions and isolated areas. • Difficult to distinguish between other warnings such as tornados. • May not be heard during the night or severe weather conditions.
B. Mass Media	• Applicable as one aspect of a warning system; may reach large portion of populace quickly. • Radio is more reliable than television because of potential power failures and greater audiences during severe weather. • Generally not effective at night; or for the deaf. • Warnings are often generalized on a regional basis.
C. Telephone	• Applicable to individual structures, motels, businesses, hospitals, etc. • Unreliable as a mass warning system because of power failure, busy lines etc.
D. Public Address System	• Feasible for most situations by providing personal warning and instructions to relatively large numbers of people fairly quickly. • Generally not effective at night; or for the deaf. • May be effective means of warning people in isolated or remote areas by boat, helicopter, car, etc. • May not be heard at night or inside buildings. • For streams critically prone to flash floods, warning time may prohibit use for entire threatened area.
E. Door-to-door	• Most effective method of warning and should be implemented unless warning time prohibits its use.

	• Provides personal warning and instructions with greater degree of effective response. • Effective for most residences at night.
3. Temporary Evacuation of People and Property	• Applicable where sufficient warning time permits.
4. Implementation of Temporary Protective Measures	
A. Temporary flood proofing of structures using sandbags, plywood, polyethelyne, etc.	• Most effective for protection of basements, windows, doors. • Should be limited in height to that which will not endanger the structural integrity. • Materials must be available.
B. Flood fighting efforts	• Applicable for warning times greater than 24 hours except for minimum effort of closure of sewers, floodgates, protection of manholes, etc. • May require significant manpower, materials, and equipment which may be prohibitive on short notice.

Cost Information

Costs of Major Flood Forecast Center - The costs associated with establishment and maintenance of a major flood forecasting center are summarized in Table C-2. The costs are based on the National Weather Service forecasting center located in Sacramento, California, which services over 200,000 square miles in California and portions of western Nevada and has the capability of providing forecasts to 150 locations. The costs include those pertinent to the Sacramento base station and those associated with field offices (usually for watersheds, counties) which collect area precipitation and streamgaged data using telemetry monitoring of gages and transmitting these data to the base station. Forecasts of the watershed are then transmitted back to the field offices from the base station. Of the 13 regional forecasting centers in the United States only the Sacramento, California, Slidel, Louisiana, and Portland, Oregon, offices have the capability of utilizing telemetry capability with interaction with field offices for forecasts.

TABLE C-2

APPROXIMATE COSTS OF MAJOR FLOOD FORECAST CENTERS

(Sacramento as Model)

Item	Cost
Base Station Costs	
• Installation of computer facilities (32K) and teletype communication device.	$50,000/unit
• Manpower—10 to 12 people manned 24 hours per day (25% of the time devoted to flood forecasting)	70,000/year
• Rental of space, utilities costs, etc.	2,500/year
• Continuous maintenance of building and equipment.	8,500/year
Site Data Collection Costs	
• Installation of raingage with telemetry capability which signals incremented changes in precipitation (includes battery pack).	2,000/gage
• Installation of raingage with telemetry capability that permits continuous interrogation (includes power supply and logic circuits.) Variable with type of equipment.	$ 5,000 to 12,000/gage
• Installation of recording streamgage.	10,000 to 15,000/gage
• Installation of telemetry capability on existing streamgage.	2,000/gage
• Cost of relay system. Required where telemetry radio line-of-sight communication signal cannot reach field or base station. Costs vary dependent upon location and design of relay station.	5,000 to 15,000/station
• Maintenance costs including equipment and batteries.	400/gage/year
Field Station Costs	
• Installation of mini computer (8K) for data collection and communications with base station.	8,000/unit

• Forecasting model calibration. Costs vary with complexity of stream system and whether or not floods may result from snowpack runoff.	400 to 7,500/watershed
• Manpower, maintenance, etc.	1,500 to 2,500/year

County or Community Forecast Center - Self-contained county or community forecasting centers. These systems are generally applicable where NWS forecasting centers are not equipped to interact with a field office and other measures are not effective. Table C-3 shows approximate costs.

TABLE C-3

APPROXIMATE COSTS FOR COUNTY OR COMMUNITY FORECAST CENTERS

First Costs

- Installation of 3-4 raingages w/telemetry capability
- Installation of telemetry capability on existing streamgage
- Installation of mini-computer system

TOTAL FIRST COSTS $ 15-25,000

Continuous Costs

- Maintenance of Equipment
- Manpower
- etc.

TOTAL ANNUAL COST $ 12-20,000

Automatic Alert System - Cost of implementing a flash flood automatic alert system to a Sheriff, Police or Fire station (county level). The signal is automatically activated at predetermined river stage or precipitation recording. Approximate costs are,

- Capital Costs $4,000/unit
- Continuous Costs 2,000/year

General Assistance - General assistance from the NWS in flood recognition methods such as for simplified flood forecasting charts. These costs are generally absorbed by the NWS.

- Cost Approximately, $500-1,000 per location

Costs of Warning Systems - The cost items associated with flood warning systems include purchase and installation of equipment, maintenance of equipment, and those costs incurred during a flood threat related to the warning dissemination process. For many situations the equipment costs are minimal and offset by using existing available equipment or coordinating the flood warning equipment required with that necessary for other disasters. Cost items identified are presented in Table C-4.

TABLE C-4

COST ITEMS FOR WARNING SYSTEMS

Purchase and installation of equipment

- Sirens
- Radio communications equipment
- Public Address systems
- Mass telephone communication network

Maintenance of equipment

Warning dissemination process during flood threat

- Mass media
- Public address systems
- Equipment usage
  a. helicopters
  b. boats
  c. automobiles
- Telephones
- Manpower required to disseminate warnings
- Tone activated radios

Cost of Flood Fighting - Flood fighting requires the use of stockpiled equipment and materials, force account contractor equipment and manpower, and public agency and private individual manpower. Team leaders and foreman will require training, and pre-prepared tasks (for issuance to contractors) defined. Initially, equipment and materials must be acquired, stored, and kept ready for use. When flood fighting has been performed, certain materials will require replacement (such as sandbags), and clean up and restoring equipment for future use will be necessary. The costs for flood fighting are therefore comprised of administration and training cost, initial outlays for equipment and materials, and recurring costs for storage, replacement of damaged or expendable items, maintenance and flood event manpower, equipment rental and similar event-by-event costs. Stockpiled equipment and materials would include such items as sandbags, generators, pumps, hoses, floodlights/portable lights, shovels, boats, fuel and certain emergency food and medical supplies. Force account rental during a flood event might include general labor, heavy construction equipment such as dozers, graders, etc., temporary shelter, boats aircraft/helicopters, pickups, etc. Care should be taken when estimating costs to recognize that normal wage rates and rental rates will probably not prevail during a flood emergency.

Costs of Temporary Flood Proofing - The temporary flood proofing costs associated with a typical residence include:

- Purchase and placement of sandbags.
- Purchase and placement of plywood/water preventative material.
- Labor required for limited evacuation and reoccupation of basement and first floor.

Costs of Maintenance of Vital Services - The maintenance of vital services for a flood event include the shutting off of utilities, sewage, water supply, etc., in threatened areas and maintaining similar services for the remainder of the community and for those evacuated from their residence. Also, included are fire protection, police and surveillance, traffic control and adequate medical assistance. The costs items for maintenance of vital services are primarily manpower, however, equipment costs of these activities may also be singificant in certain flood situations.

TABLE C-5

COST ITEMS FOR MAINTENANCE OF VITAL SERVICES

- Traffic Control (manpower and equipment)
- Fire Protection (manpower and equipment)
- Medical Assistance
  - Medical Staff
  - Ambulances
  - Medical Supplies
- Surveillance and Protection of Property (manpower and equipment)
- Utilities (manpower and equipment)

Cost of Post-Flood Reoccupation and Recovery - The post-flood recovery and reoccupation costs should reflect those items directly incurred by the implementation of a preparedness plan during a flood event. The costs of rehabilitation of structures, removal of sediment, etc., would occur without a preparedness plan and should not be included when estimating the cost of this measure.

TABLE C-6

COST ITEMS FOR POST-FLOOD REOCCUPATION AND RECOVERY

- Return of services modified by preparedness plan.
  - Utilities
  - Water supply
- Removal of temporary flood loss reduction measures.
  - Temporary flood proofing
  - Flood fighting materials

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4. Owen, H. James, "Guide for Flood and Flash Flood Preparedness Planning," Prepared for the National Oceanic and Atmospheric Administration, National Weather Service, April 1976.

5. Susquehanna River Basin Commission, "Planning Guide, Self-Help Flood Forecast & Warning System, Swatara Creek Watershed, Penna.", Mechanicsburg, PA., November, 1976.

6. Susquehanna River Basin Commission, "Neighborhood Flash Flood Warning Program Manual", Mechanicsburg, PA, October 14, 1976.

APPENDIX D

SPECIAL CONSTRUCTION MEASURES TO MITIGATE FLOOD LOSSES IN SINGLE FAMILY RESIDENTIAL CONSTRUCTION[1]

Special construction measures to mitigate flooding losses, which are appropriate for new single family detached residential construction, and appropriate limits for their application, are presented and discussed in the several categories below.

Measures Which Normally Involve No Increased Initial Construction Cost

1. Building superstructures should be anchored to building foundations in accordance with MPS requirements. This will protect against superstructure displacements caused by low flood flow velocities or flotation. (Peripheral benefits should be realized during some windstorms or earthquakes).

2. Fuel tanks located inside of buildings should be positively anchored to resist maximum flotation or overturning forces, should be vented directly to the atmosphere outside of the building, and the vent discharge should be above normal first floor eaves level. This will prevent escape of fuel and consequent nearly irremediable fuel saturation of dwelling interiors in the event of flooding. (There may be peripheral benefits in the event of earthquake and in terms of fire hazard reduction). We cannot justify prohibition of fuel tank installations within dwellings.

3. Heating and air conditioning ducts located below the first floor level should be provided with drains so they will not collapse under the load of retained water as flood waters recede. One way to assure such drainage would be to install an oversized bottom panel at the low point of ducts, fastening the panel to the duct with a small number of undersized screws, so the panel will either buckle or the screws tear out under load. Such a panel could have tape or other suitable material between contacting surfaces, to minimize noise when air circulating fans are operating.

4. All electrical receptacle outlets and electrical equipment located less than three feet above the elevation of the first floor should be on branch circuits separate from those serving overhead lighting fixtures. Circuits serving lower level outlets or equipment should be clearly identified in the panel or cabinet enclosing the fuses or circuit breakers. One benefit of this measure is to permit use of lighting as flood waters rise, increasing the opportunity for relocation of residential contents. Another benefit is the capability to disconnect circuits exposed to flooding, to prevent electrical discharges into flood waters.

5. Finish flooring in basements should be water damage resistant and dimensionally stable in the event of protracted immersion. This measure is wise in any basement, regardless of its seeming exposure to flooding.

6. Gas piping within any building should have a minimum longitudinal gradient or slope of ⅛ inch per foot and should be provided with a removable and replaceable drain plug at its low point within the dwelling. This simplifies drainage of gas lines after flooding and is already at least partially required by many local plumbing codes.

[1] Prepared by D. Earl Jones, Jr. For additional information see "Floodproofing Limitations and Flood Loss Mitigation" and "The Economics of Water-Resistant Construction" by D. Earl Jones, Jr., in **Proceedings of a Joint ASCE — Engineering Foundation Conference on Flood Proofing and Flood Plain Management,** 1977.

7. Paints and other applied finishes used in basements should be water damage resistant. Such a paint is defined as one that, after protracted immersion will remain serviceable and attractive after surface washing. Water damage resistance is **not** equated with impermeability, as microporosity is essential for vapor transmission.

8. Positive drainage of basement ceilings should be assured so that finished ceilings will not collapse due to the weight of retained water as flood waters recede. This may be accomplished most simply by making certain that ceiling materials do not butt against structural framing and that moldings or other trim clear the ceiling. In establishing clearances, potential sealing effects of future painting should be considered. When properly nailed, drywall ceilings not damaged by debris are observed to survive flooding quite well.

The following measures are recommended for new single family detached residential construction located below the 100 year return frequency flood level reflected in plans for some Corps of Engineers flood control projects or defined as the Intermediate Regional Flood in their Flood Plain Information Study reports, and/or below the 100 year frequency flood limits (boundary of the flood hazard area) defined on the flood hazard area maps produced by the Federal Insurance Administration:

9. All cabinetry installed in basements should be water damage resistant and dimensionally stable in the event of its protracted immersion. The simplest compliance with this measure would be to use metal cabinetry. Home purchasers may be less than enthusiastic about the use of metal. As basements can flood due to causes other than surface water runoff, use of this measure in any basement location would be wise, regardless of flood hazard exposure.

10. All cabinetry installed less than three feet above the first floor elevation of dwellings should comply with 9, above, if the first floor elevation will be lower than the 100 year return frequency flood elevation. (Although new construction having first floors so situated generally is ineligible for endorsement for HUD-FIA mortgage insurance, special situation elevation waivers have heretofore been issued, to which this measure should be specifically applicable.)

11. Carpeting and carpet cushions installed in basements should be manufactured exclusively from materials that will suffer no permanent damage from protracted immersion. Salvage is more economical than replacement. This is recommended practice in **any** basement.

12. Materials used for finished floors on the first floors of dwellings should be water damage resistant and dimensionally stable in the event of protracted immersion. This will minimize the need for flooring removal and replacement after flooding and will preclude structural damage from expansion of flooring materials due to wetting. This measure is recommended where floor elevations will be less than one foot above the 100 year return frequency flood level.

13. Carpeting and carpet cushions installed as finish flooring on the first floors of dwellings should comply with measure 11, above, when the elevation of the finished floor will be **less than one foot** above the 100 year return frequency flood elevation.

Measures Which Normally Involve Increased Initial Construction Cost

14. The width of interior basement stairways, clear of the handrail, should be at least four feet, and the minimum dimension of the landing at the head of the stairway should be at least 42 inches, to facilitate relocation of basement contents in the event of impending flooding. The added space will permit relocation assistance by children and other persons having minimal

physical strength. This measure is recommended where the elevation of the first floor **will be less than two feet** above the 100 year return frequency flood elevation. It is noted that this measure of itself will not mitigate potential flooding losses, but it will permit mitigation of dwelling contents losses. An average reduction of $400 (8/74 replacement costs) during a flood, by contents relocation, has a present value in excess of the added initial construction cost at the recommended implementation elevation, and greater present value at lower elevations.

15. Placement of up to two feet of compacted fill, to elevate the building site for a non-basement building to above the 50 year return frequency flood elevation, has a present value in excess of its added cost almost everywhere. Where the 100 year return frequency flood elevation is less than one foot higher than the 50 year return frequency flood elevation, such filling will assure minimal average annual flooding damages.

16. The base of the hot water heater should be at least 12 inches above the finished first floor elevation. This is recommended in all situations where the finished first floor elevation will be below the 200 year return frequency flood elevation.

17. The base of heating and air conditioning equipment designed to operate on liquid or gaseous fuels, or that contains electrical motors or operating controls, should be at least 12 inches above the finished first floor elevation. This is recommended in all situations where the finished first floor elevation will be below the 200 year return frequency flood elevation.

18. All adhesives used in flooring, wall, or partition systems should be water resistant, as commercially defined. This is justifiable below the 200 year frequency flood elevation but is recommended at all elevations regardless of the degree of flood hazard exposure.

19. A positively functioning manual sewer cutoff valve should be installed in the sewer lateral outside of any dwelling having a basement if the basement floor will be below the 100 year return frequency flood level. Check valves are not considered comparable to manually operated valves. Appropriate lves can prevent sufficient damages from surface water flooding to justify their initial installation cost. Appropriate operation of such valves will have added value whenever backflow from surcharged sewers may be prevented.

20. Basement floors should be underlain by a layer of course crushed rock or clean gravel (0% passing the 1/2 inch screen) at least 6 inches in compacted thickness. The floor should have a weakened area located near its center, but not beneath a partition or probable appliance location. Concrete thickness in the weakened area should not exceed two inches and its surface should be scribed to a one inch depth, to assure its rupture in advance of rupture of the surrounding floor if hydrostatic uplifting forces develop. The weakened area should have a minimum area of 20 square feet. The added cost of this item is justifiable where either footing drains are used or the ground outside of a dwelling is permeable, and where the exterior ground grade is below the 75 year return frequency flood elevation. Use is recommended when the first floor elevation of a dwelling will be at or below one foot above the 100 year return frequency flood elevation, as hydrostatic uplifting forces can develop from causes other than general flooding.

21. The lower portion of each wall of a basement should have a weakened point for entry of ground water, percolating surface runoff waters, or piped drain backwaters, so that hydrostatic forces acting against the wall will be relieved by water entry into the basement before induced wall collapse. Such entry points should be connected (interconnected) by a layer of permeable

backfill, for which naturally permeable soils may suffice. This measure is recommended where first floor elevations will be lower than one foot above the 100 year return frequency flood elevation. Note that basement floors generally burst before walls unless scour is involved; that hydrostatic pressures against walls generally are somewhat less than those beneath basement floors; and that the weakest point of a block wall subject to exterior hydraulic loads will be above basement floor level because of the restraint floors and superstructure offer against bending.

22. Each basement window, including single pane windows in doors, should have a line scribed on the interior of the pane two inches above and parallel with the bottom edge of the window, and extending between points two inches from the vertical edges of the glass. This is to assure failure of the glass and flooding of the basement if appreciable outside flooding occurs, so that potentially damaging hydrostatic forces may be counterbalanced by interior water loads. This is recommended where finished first floor elevations will be below the 200 year return frequency flood elevation. Visibility of the scribed line will be reduced if it is filled with dark-colored paint. Double-glazed windows should not be scribed.

23. No dwelling should be sited with its finished first floor less than 1.5 feet above the lowest point on the crown of any roadway crossing a channel, drainageway or stream within 1/4 mile downstream from the dwelling. Similarly, the minimum finished grade outside of a dwelling having a basement should be at least one foot above the lowest point on the crown of any roadway crossing a channel, drainageway or stream within 1/4 mile downstream from the dwelling. These two siting precautions are unquantifiable in terms of benefits but are major considerations in avoiding flooding losses.

Flood Loss Mitigation Measures that Normally Involve Increased Initial Construction Cost and that have Controversial Aspects:

The following measures each will mitigate potential flooding losses to such an extent that their present value is believed to exceed their added construction cost at locations where the finished first floor of a dwelling will be at or below the 100 year frequency flood elevation. They each involve some unresolved cost or availability issue, or some other uncertainty.

24. Water resistant interior dwelling doors are not generally available. If they become available, their installation would be recommended where the finished first floor will be lower than one foot above the 100 year frequency flood elevation, provided they are competitively priced. No present value analysis was made, because of the lack of cost information.

25. Plywood used in dwelling interiors, for any purpose, should be what formerly was described as "Exterior" grade, to minimize delamination in the event of flooding. We understand that manufacture of "Interior" grade plywood is being suspended in the USA. Some imported plywoods and nearly all laminated wood panelings are made with adhesives that are not water resistant. Importers should be urged and manufacturers encouraged to upgrade such products. Present values of such requirements were not evaluated for lack of cost information, but we believe they would be justifiable because of high removal and replacement costs.

26. Thermal insulation of sound-deadening materials installed in exterior walls, partitions and floors, at elevations below the windows of the first floor, should be impermeable to water. An impermeable material is defined as one that will absorb less than 5 percent water (by weight) if immersed in water for 24 hours. Such a practice would produce a major flood loss mitigation

benefit where first floors will be less than one foot above the 100 year flood elevation, but is currently controversial because available impervious insulating materials are made from plastics whose combustion produces toxic or noxious gases. Logic suggests that such insulation will be shielded from interior fires in homes far longer than life would be possible within the dwelling, so its use is recommended. It also is recommended that manufacturers be stimulated or encouraged to develop an impervious insulating material that will be competitive with permeable insulations and that will have no inherent adverse characteristics. This should be a high priority subject for research and development because of the potential for significant flood loss mitigation is an estimated 10 percent or more of the single family dwelling construction market.

APPENDIX E

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